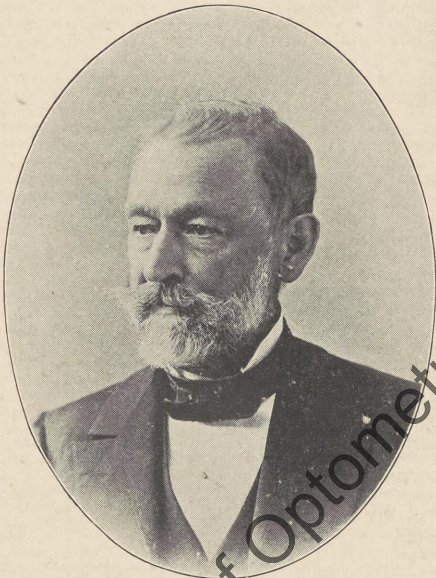


CHARLES A. SPENCER,

Greatest American Optician,—Born, 1813; Died, 1881.

[ See page 225.

# HAND-BOOK

FOR

# OPTICIANS.

A TREATISE ON THE OPTICAL TRADE, AND ITS MECHANICAL MANIPULATIONS.

BY

W. BOHNE,

OPTICIAN.

535

SECOND EDITION,

THOROUGHLY REVISED AND GREATLY ENLARGED.

WITH ILLUSTRATIONS.

PUBLISHED BY THE AUTHOR,
(With A. B. GRISWOLD & CO.)
No. 119 CANAL STREET, NEW ORLEANS, LA.
1892.

"PRESS" PRINT, 50 BIENVILLE ST., N. O.

# PREFACE TO SECOND EDITION.

Since the "Hand-Book for Opticians" made its first appearance, I have, to my greatest satisfaction, observed a general wholesome stir among the opticians, manifesting itself by several new publications in the same line; by the increased attendance of young opticians at the different Ophthalmic Colleges, and by the issue of a "Monthly Journal" in our interest. This was my reason for taking another step in the further instruction of my companions. The first edition was merely a feeler to ascertain if a book, so different from other instruction-books, was wanted or rather needed. The favorable reception it received, even outside of the trade, induced me to extend its usefulness by adding some information which I purposely omitted before, judging that the medical faculty would properly attend to the theoretical part of our occupation. But their writings demand a partially scientific education which most of us, simple opticians, have not received. My explanations may not be strictly professional; but a diligent reader will readily understand them, and—that is, in my opinion, the principal object of all instructions.

The treatise on the Development of the Optical Trade (Chap. XXVI), although enlarged, is still insufficient in its present state; and to compensate for its short-comings, I have added the next chapter, in which the gradual progress of the optical science is individualized by a brief history of the lives of those men, who attributed to the advancement of our trade and science in general.

The large space I devoted to the memory of the late Charles A. Spencer may be a surprise to many opticians

who perhaps never heard of him; he is better known in medical circles than among his own trade-companions; better in Europe than in America. Even the cyclopedists have neglected him; he went to the grave almost unknown to his neighbors. Spencer was the first optician who produced objectives of wide angles, and inspired the studies of scientific men in all parts of the world. Without his genius, many of the marvelous discoveries accomplished by the microscope could never have been made. Our country did herself a great wrong in not making more of her gifted son, and it is the sacred duty of the American opticians to prevent his name from being forgotten.

It is with great pleasure that I acknowledge my indebtedness to Dr. H. D. Bruns, Mr. H. Ginder, Mr. Chas. F. Prentice, Mr. J. M. Johnston and Mr. G. C. Ridgway, for their valuable assistance and kind advice in the preparation of this work.

NEW ORLEANS, 1892.

W. BOHNE.

# EXTRACT FROM PREFACE OF FIRST EDITION.

My object is to instruct the rising generation of our trade, and elevate them to the position of the great progress optical science has made within the last quarter of the century. I am well aware that the present work is not as complete as it ought to be, because every chapter is composed and written as *something new*. There is nothing previously published about these subjects, and my book may be the pioneer to open the road for other writers. Almost every trade has its literature or hand-book of the secrets peculiar to its business; but the optical trade, as regards the mechanical part of it, has none whatever.

What I offer here is the result of a life-long experience and of numerous investigations. Workmen who find any error, or who know better methods, are cordially invited to communicate their information to the author, who will acknowledge his obligation in a future edition.

Let us remove the curse of all progress—the keeping of our secrets and little tricks to ourselves. Let every workman withdraw the restriction placed upon his fellow-laborers, forbidding them to enter his shop, in order to prevent them from profiting by his skill. This is the proper way to elevate our trade to a commanding position, so that we may no longer be confounded with street-fakirs and mere spectacle-vendors.

My book will furnish to any young man a solid foundation of what he ought to know, and will enable him to master all difficulties he may encounter in the pursuit of his occupation. As there is no telling what demand will be laid on his ability in the immediate future, he should

try to understand thoroughly the fundamental laws of his trade and become a competent workman.

Chapter V explains all about the *optical line* and *center* in lenses, and chapter VII, of the setting of *compound lenses;* both proved for many years to be the stumbling-block of our efficiency and ability. Chapter III treats of *pebbles*, but differs from anything heretofore published. I hope that my experiment will be repeated by opticians and scientists in order to finally settle the vexatious question: "Shall pebbles be used or not?" I am anxious to hear what others have to say about them.

The history of the "Invention and Introduction of Spectacles," is the first attempt at collecting the scanty materials about this important subject, and is far from being what its title indicates. Those of my readers, who are in possession of facts concerning this matter, will kindly communicate them to me for future use.

New Orleans, 1888.

W. BOHNE.

# CONTENTS.

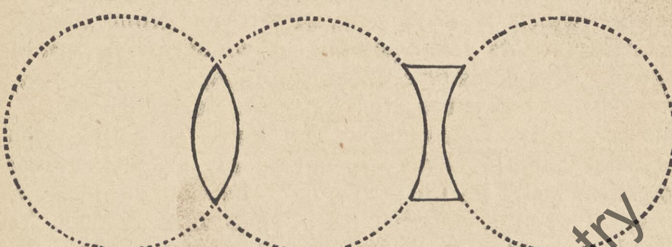
## ABBREVIATIONS.

| | | |
|---|---|---|
| D | = | diopter. |
| ax | = | axis. |
| C. or cyl. | = | cylindrical. |
| cc | = | concave. |
| cm | = | centimeter. |
| m | = | meter. |
| mm | = | millimeter. |
| S or sph. | = | spherical. |
| — | = | concave. |
| + | = | convex. |
| ⌢⌣ | = | combined with. |
| ° | = | degree. |
| ′ | = | foot, also a minute. |
| ″ | = | inch, also a second. |
| ‴ | = | line, the twelfth part of an inch. |

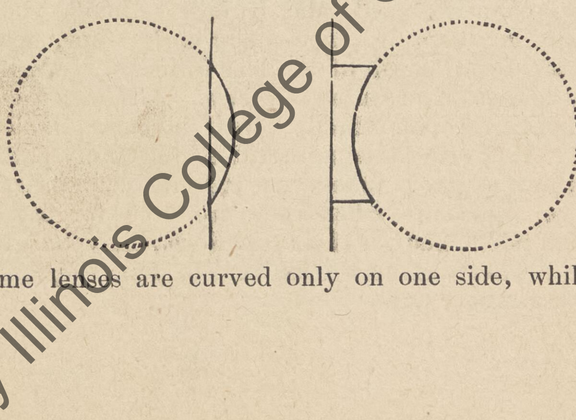
## CHAPTER I.

### Inch and Metric Systems.

Spectacle lenses are made of glass or pebbles ground to a spherical form, either convex or concave, by means of tools which are segments of a ball or sphere.

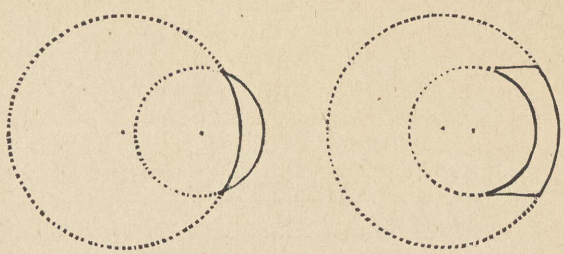


The dotted lines represent the whole spheres of which but segments in form of shells or cups are employed for the grinding of lenses. If we use the inside or hollow part of the shell, we produce a convex lens, while the outside or rounded part is employed for concave lenses.



Some lenses are curved only on one side, while the

other side is flat; they are called plano-convex or plano-concave.



Periscopic lenses are ground by spheres of different sizes, as shown in the above cuts.

We have, therefore, three kinds of cx, and three kinds of cc lenses. Cx lenses collect behind them, by refraction, the greatest portion of the rays falling on their surface at one common point, called the "positive focus," which is nearer to, or further from the lens according to its focal power. A concave lens, on the contrary, disperses or scatters the rays, and has a "negative focus," because we only can neutralize it by a plus or positive focus lens. The term "negative lens" does not exactly cover the nature of a concave lens; we can measure its focus also by reflection, which gives *in front* of it a positive focus, just as a convex lens will do *behind* it when measured by refraction. For instance, fasten a white card at the end of a foot-rule, go to a glass-door or window, hold the ruler so that the card is between the window and the lens, approach the concave lens until you get a sharp image of the window on the card; then see on the ruler how many inches the lens is from the card, and if it is a double concave, multiply by two, if plano-concave, by four, and you have the focal length of the lens in inches. Periscopic lenses cannot be measured this way. Although the latter are highly recommended by their inventor, *Wollaston*, and by other celebrated authorities, I, for my part, find that the stronger numbers are extremely unpleasant to the eye, especially when they are used for cataracts. All that is claimed for their superiority may be granted to the weaker numbers from one to four *diopters*, but not for stronger ones.

Here arises the question, which of the three words is right and should be used: *Dioptric*, *Dioptry* or *Diopter*? These three scientific terms are derived from the Greek verb *dioptomai* (*dia*, through, and *optomai*, I see), I see through, I see completely. In Modern Greek *dioptres* means spectacles. "Dioptrique" (English "dioptric") has been adopted by the French in connection with optical measurements, as a substitute for the term *meter*, which latter, although denoting measure in general, has no specific application to optical measurements. Originally, the French word dioptrique, both by derivation and common use, does not include any idea of measure or measurement whatsoever, it only refers to the refraction of light. It is simply an old word with a new technical meaning, contrary to the logical rules of language, like many other words of foreign extraction. Dioptrique not being a noun but an adjective, and not sanctioned by scientific usage, at least not yet in the English speaking world, we should exclude it henceforth from our optical terminology in regard to measurement. Likewise objectionable is the noun "Dioptry" as a term for expressing optical measures.

The word *diopter*, considered as a contraction from "dioptometer," is evidently the most suitable for our purpose, and is strictly analogous to words like barometer, thermometer, etc., also employed for different measurements. The word "diopter" also denotes a geometrical instrument used for leveling purposes—The substitution of the word diopter for meter has been adopted by oculists and all first-class opticians since 1875, in order to introduce a uniform measurement instead of the old inch measure, which considerably differs in length in the different countries. So is

| | |
|---|---|
| 1 Paris inch | 27.07 mm. |
| 1 English inch | 25.3 " |
| 1 Austrian inch | 26.34 " |
| 1 Prussian or Rheinish inch | 26.15 " |

and one meter contains 37 Paris inches,
" " " 39.37 English inches,
" " " 38 Austrian inches,
" " " 38.23 Prussian inches.

2

This explains why imported lenses never correspond with our numbers and have to be remeasured. When we order No. 20 ($\frac{1}{20}$), we find them generally to be 22; and it is only by keeping in stock the half numbers, as $5\frac{1}{2}$, $6\frac{1}{2}$, etc., and odd numbers like 17, 19, etc., that we are able to fill the orders of oculists. The trouble is increased that some oculists have their test-lenses measured by the French inches, some by the Rheinish measure, others by the English or American, and as the same differences occur in the measurement of lenses offered by different manufacturers, the confusion is a general one.

This trouble is definitely overcome by the introduction of the *metric system*, as the meter is independent of the special measurements of different countries. The inch system has also the great inconvenience that the *unit* represents a lens of 1 inch focus, and that we have to express the strength of all lenses weaker than No. 1 in fractions. A lens which we call No. 10, is really one tenth as strong as No. 1, and has to be written $\frac{1}{10}$, and two lenses of this strength combined are $\frac{2}{10} = \frac{1}{5}$ or No. 5. But this was not the only disadvantage of the inch system; we were also obliged to carry an unnecessary assortment of numbers in stock which were utterly useless. I only mention here the numbers of lenses found in the catalogues of importers from 40 going up in even numbers to 60. Such numbers as 42, 44, 46, etc., are of no earthly use, as will be seen by the following table, showing the differences in strength between those numbers which the better informed opticians kept in stock. The differences between

| | | | | | | |
|---|---|---|---|---|---|---|
| 5 | and | $5\frac{1}{2}$ | in inches is | $\frac{1}{55}$, | in diopters | 0.73 |
| $5\frac{1}{2}$ | " | 6 | " | $\frac{1}{66}$, | " | 0.60 |
| 6 | " | $6\frac{1}{2}$ | " | $\frac{1}{78}$, | " | 0.51 |
| $6\frac{1}{2}$ | " | 7 | " | $\frac{1}{91}$, | " | 0.44 |
| 7 | " | $7\frac{1}{2}$ | " | $\frac{1}{105}$, | " | 0.38 |
| $7\frac{1}{2}$ | " | 8 | " | $\frac{1}{120}$, | " | 0.34 |
| 8 | " | 9 | " | $\frac{1}{72}$, | " | 0.56 |
| 9 | " | 10 | " | $\frac{1}{90}$, | " | 0.44 |
| 10 | " | 11 | " | $\frac{1}{110}$, | " | 0.36 |
| 11 | " | 12 | " | $\frac{1}{132}$, | " | 0.30 |
| 12 | " | 13 | " | $\frac{1}{156}$, | " | 0.25 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 13 | and | 14 | is in inches | $\frac{1}{182}$, | in diopters | 0.22 |
| 14 | " | 15 | " | $\frac{1}{210}$, | " | 0.19 |
| 15 | " | 16 | " | $\frac{1}{240}$, | " | 0.17 |
| 16 | " | 18 | " | $\frac{1}{144}$, | " | 0.28 |
| 18 | " | 20 | " | $\frac{1}{180}$, | " | 0.22 |
| 20 | " | 24 | " | $\frac{1}{120}$, | " | 0.33 |
| 24 | " | 30 | " | $\frac{1}{120}$, | " | 0.33 |
| 30 | " | 36 | " | $\frac{1}{180}$, | " | 0.22 |
| 36 | " | 40 | " | $\frac{1}{360}$, | " | 0.11 |
| 40 | " | 48 | " | $\frac{1}{240}$, | " | 0.17 |
| 48 | " | 60 | " | $\frac{1}{240}$, | " | 0.17 |
| 60 | " | 72 | " | $\frac{1}{360}$, | " | 0.11 |
| 72 | " | 90 | " | $\frac{1}{360}$, | " | 0.11 |

In order to have a full understanding of the above table, let us take a patient who complains of his spectacles being too weak. We find them by measuring to be No. 10. If we combine with them our weakest inch-number in stock, No. 90, we increase their focal strength to No. 9. — Another patient is wearing No. + 12; he finds them too strong, but is well pleased after we have added — 0.25 diopter. According to the above table we find that we have decreased the strength of his spectacles from + 12 to + 13. — The differences between two numbers, from No. 13 up, are not much more than $\frac{1}{4}$ diopter (0.25 D), in some cases less than $\frac{1}{8}$ diopter, and the differences of all the intermediate numbers, not mentioned in this list, are so little that they amount to almost nothing, and should be omitted in our stock of lenses as unnecessary.

Spectacle lenses are manufactured in such quantity and so cheap, that we cannot expect them to be mathematically correct like the lenses of scientific instruments, else they would be considerably dearer. The careless way in which many people put on their glasses is no encouragement to manufacture perfect and high-priced lenses; they would only prove to be a waste of labor and money. Most people have no more use for such perfect spectacles than an Indian has for classic music. But there is one essential requirement without which a lens is totally worthless, *i. e.* they should be well *centered.* The center of a lens is the highest or lowest

point of its surface (according as it is convex or concave); and as each side is finished separately, these centers should be exactly opposite each other, so that a line drawn through them is at a right angle with the plane of the lens from edge to edge through its middle. The test for a well centered lens is to get in sunlight a sharply defined small circle, and the smaller this circle the more perfectly the lens is centered. All *common spectacles* are badly finished in this respect, and should not be sold by any conscientious optician. If people are willing to injure their eyesight for the sake of a few dimes, let them do so; but we should rather lose the sale of a good article than be parties to such reprehensible dealings. The traffic in "eye-killers" should be prohibited by law, as druggists are forbidden to sell *poison* without discrimination.

The first qualification of an optician is his ability to measure lenses in inches as well as in diopters. The inch system is not so simple as many opticians consider it to be; it includes some scientific points which are based on the refractive power of the different sorts of glass (Chap. XIII). The same curve, or radius of curvature, does not always produce the same focal power. If the grinder takes, for instance, slabs of flint, crown glass and pebble, and finishes them with the very same mould or segment of a ball, he will find that his lenses are of different strength, because the index of refraction of those three kinds of material is of different power. But this scientific distinction between the "radius of curvature" and the "actual focal power" of a lens is of little importance to the average optician, who has only to do with its focal distance, indicated either in inches or diopters. Let us, therefore, turn our attention to the practical method of measuring lenses by the *focal distance* in inches, and ignore entirely by what curve the lens was ground. There is a simple way to determine if a lens is convex or concave, which, in weak numbers, is sometimes a difficult task for an inexpert eye. For this purpose we hold the lens a few inches from the eye, and look through it at a distant object; then we move the lens slowly to the right and left, or up and down,

and when the object apparently moves in the same direction as the lens, it is *concave*; if it moves in the opposite direction, it is *convex*. Even the weakest lens, say 0.25 D., shows a distinct movement one way or the other. These movements are more easily detected in weak lenses when they are held at a greater distance from the eye.

If you have in your store or workshop a suitable place to fasten permanently a rule of 40″ in length, horizontally, with a white card attached at zero, and counting from that point in the direction of a conspicuous object, for instance a window or a railing, 20 or more feet away, it is easy to find the focus by moving the convex lens back and forth upon the rule until you have a well-defined picture of the window on the card. This figure is always reversed, the reason for which will be explained in the next chapter. As soon as the figure shows clearest, you observe on the rule the number of inches, which will be also the number of the lens. There is no difficulty in measuring in this way convex lenses up to 30″; beyond that, it requires greater care and some practice to distinguish the faint picture on the card, especially in cloudy weather. The surest way to measure weaker lenses than 30″, is to place two together and measure them conjointly. Two lenses of 48 will give 24, and one lens separate will be again $\frac{1}{48}$ or half the strength of $\frac{1}{24}$. But if we have two lenses apparently of the same strength, which are actually 60 and 72, how can we ascertain that they are of different strength? The ruler will be useless to us, even if we would lengthen it sufficiently. Here we have to fall back on our own eyes, and let them render judgment. Take for instance a folding foot-rule of 2′, and open it sufficiently to introduce a pin-head between the open ends. You will hardly think that this little opening has much effect on the parallelism of the two lines. But when we place this foot-rule so that the continuation of one branch strikes a point several hundred feet away from us; then, without moving the rule, and following with our eye the other line, we will see what effect this little opening has. You will understand by this, that you have to compare such weak lenses

by looking at remote objects. If there is convenient a roof of a house one or more hundred feet away from you, take the two lenses, 60 and 72, one in each hand, hold them edgewise together, and look through them at arm's length at the roof; move one or the other lens up or down till you see the lower line of the roof *straight* through both glasses. Now look, without moving the lenses, at the upper line, and you will find that it is higher in one lens, which is, of course, the stronger one (No. 60), as it is of greater magnifying power.

As regards the measurement of concave lenses, we have to deal principally with their "negative" nature, the opposite of the "positive" character of convex lenses. The comparatively easy task of providing ourselves with a full set of convex test-lenses, facilitates the otherwise difficult job to determine their strength by means of reflection of the weaker numbers. Besides we would be entirely helpless in this regard without the assistance of convex lenses, in measuring periscopic concave lenses, which cannot be done at all by reflection. But with a full set of convex lenses we can readily neutralize concave lenses of any strength and shape, and find their exact focal power without the least trouble. If you have a concave lens of which you do not know the number, pass before it different convex lenses till you come to that one which makes them both together appear plane, and the number of the convex lens is the number of the concave one: $+ \frac{1}{7}$ and $- \frac{1}{7}$ is 0, or plane.

The principle on which the manufacture of periscopic lenses is based, needs a short explanation. The peculiar shape of a periscopic lens, also called Meniscus, is indicated by "concavo-convex," and its strength is the sum of its relative curves. If one side represents $- \frac{1}{20}$ ($-$ 2 D), and the other $+ \frac{1}{8}$ ($+$ 5 D), we have a lens of periscopic convex $+ \frac{1}{13}$ ($+$ 3 D). If we reverse the signs, so that one side is $+ \frac{1}{20}$ and the other $- \frac{1}{8}$, then we have a periscopic lens of $- \frac{1}{13}$, or $-$ 3 D. A little reflection will convince us of the absurdity of making cataract lenses in this form. The extreme convexity of one side will cause such an aberration of light, that only the smallest center-part of the lens will be useful and pleasant to the eye.

The unit of the *metric system* is based on the length of a meter, which is 39.37 American inches, and is expressed by the sign 1 D. Therefore, two diopters will be = 19.68″, and 3 D = 13.12″. But to simplify their calculations and to avoid the complicated fractions, we may take the meter at 40 inches, and we will be near enough for all practical purposes. The annexed table will show the nearest approximation of both systems; the small numbers give the exact value of diopters in American inches:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diopters: | 0.25 | 0.50 | 0.75 | 1.00 | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 |
| Inches: | 160 | 80 | 53 | 40 | 32 | 26 | 23 | 20 | 18 | 16 |
| | 157.48 | 78.74 | 52.49 | 39.37 | 31.49 | 26.24 | 22.49 | 19.68 | 17.49 | 15.74 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diopters: | 2.75 | 3.00 | 3.25 | 3.50 | 4.00 | 4.50 | 5.00 | 5.50 | 6.00 | 6.50 |
| Inches: | $14\frac{1}{2}$ | 13 | 12 | 11 | 10 | 9 | 8 | 7 | $6\frac{1}{2}$ | 6 |
| | 14.31 | 13.12 | 12.11 | 11.24 | 9.84 | 8.75 | 7.87 | 7.15 | 6.56 | 6.05 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Diopters: | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 16 | 18 | 20 | 40 |
| Inches: | $5\frac{1}{2}$ | 5 | $4\frac{1}{2}$ | 4 | $3\frac{1}{2}$ | $3\frac{1}{4}$ | 3 | $2\frac{3}{4}$ | $2\frac{1}{2}$ | $2\frac{1}{4}$ | 2 | 1 |
| | 5.62 | 4.92 | 4.37 | 3.93 | 3.57 | 3.28 | 3.02 | 2.81 | 2.46 | 2.18 | 1.96 | 0.98 |

Of these numbers there are only 53, 23 and $14\frac{1}{2}$ not common to the old inch system, but the next numbers in inches may be substituted till we can provide for their equivalents in diopters. I do not recommend to fill the orders of oculists in an inaccurate way, but we have seen before, that the difference between two numbers or half numbers amounts to very little, and is of no consequence to the wearer.

The great advantage of this new measurement is that it enables us to make calculations and combinations of lenses without the least trouble, while the old way in inches is more or less difficult. Suppose somebody is wearing $+ \frac{1}{26}$, but cannot see well, and we add another lens $+ \frac{1}{40}$, by which combination he sees perfectly; then we have to calculate in this way:

$\frac{1}{40} + \frac{1}{26} = \frac{26}{1040} + \frac{40}{1040} = \frac{66}{1040} = \frac{1}{16}$ (about), or 16 inches. In diopters it is quite simple: $\frac{1}{40} = 1$ D, and $\frac{1}{26} = 1.50$ D, and both together 2.50 D = 16″.

To give another illustration of the difficulty in making correct combinations by the inch system, we will take an achromatic objective lens, composed of a crown glass of $4\frac{1}{3}$ inches, and a flint glass of $7\frac{2}{3}$ inches. These two

lenses combined give a lens of + 10″ focus, and the regular way of making the calculation is this:

$$+ 4\tfrac{1}{3} = \tfrac{13}{3} = 1 \div + \tfrac{13}{3} = + \tfrac{3}{13}$$
$$- 7\tfrac{2}{3} = \tfrac{23}{3} = 1 \div - \tfrac{23}{3} = - \tfrac{3}{23}$$

by reducing these fractions to a common denominator, which is 299, we get for $+ \frac{3}{13} = + \frac{69}{299}$, and for $- \frac{3}{23} = - \frac{39}{299}$, added together gives $+ \frac{30}{299}$ or $\frac{1}{10}$ inch focus. All this trouble is avoided by turning the above lenses into diopters:

+ 4⅓ equals very nearly + 9 D
— 7⅔ " " — 5 D

added together equals + 4 D, or $+ \frac{1}{10}$″.

We have seen that the word diopter is simply a substitute for a meter, which has in America 39.37″, and in Paris 37″. Only the inches are of different length, not the meter, and to find, for instance, the difference between an American and a French foot, we have to multiply the numbers of lines in one foot (144‴) by 37, and divide the product by 39.37; the quotient will be 135.3‴, which is the length of an American foot in French lines. The French foot is, therefore, 8.7‴ longer than the American foot. To reduce inches to diopters, we divide them into 39.37 (or 40), and the product will be diopters; if we divide the diopters into 40, then the product will be inches.

# CHAPTER II.

## Different Qualities of Lenses.

Many opticians make a mistake about the comparative hardness of flint glass and crown glass, and even noted writers fall into this error. Dr. Donders, for instance, says: "Flint glass and rock crystal are harder than crown glass." I do not understand how this mistake could slip into so many medical books, as the simple test of scratching the one with the other will show at once that crown glass is harder than flint glass. Dr. Donders is not so much to be blamed for his incorrect statement as those who have reproduced his error without any investigation. I read lately in a valuable geographical work of Dr. H. Berghaus, that Geo. Washington served his country twelve years as President. I do not think less of Dr. B. for making this erroneous statement, but I censure every writer who quotes him as an authority on the subject.

We find another error in regard to pebbles, repeated in books written by careless compilers without examining the facts; and as the first writer was mistaken, all the rest labor equally under the same gross misrepresentation. I will correct in the next chapter this error which has, for years, caused an open contest between oculists and opticians. The oculists based their objections on books of high authority, and the opticians yielded to their argument from sheer want of correct information. I warmly urge both to devote some of their leisure time to investigate this question thoroughly, and try to settle it definitely.

Quartz is the principal ingredient in the manufacture of glass, which is the most transparent of all solid substances produced by man, and also the best imitation of that valuable product of nature, termed rock crystal, "pebble," or crystallized quartz. The scientific name for it is *silex*, but when it is combined with an alkali or another mineral, it passes under the name *silica*, forming with them the so-called *silicates*; so glass is a silicate of potash and lime. Quartz is composed of fifty per cent. of oxygen with about an equal proportion of its base, *silicium*, which is supposed to be a metal like potassium and sodium; but chemists cannot yet reduce it to its metallic state. In the year 1827, the base of *clay* was extracted in the form of that extremely light metal, *aluminium* (generally written *aluminum*, although the latter is but the Latin name for clay, and not for its metallic base); but the metal silicium is still waiting for its discoverer.*

To manufacture *glass*, we must take quartz or sand, — the latter is only powdered or crushed silex — and melt it together with either potash or soda with the addition of lime, borax, lead and other ingredients which facilitate its fusion. Quartz or sand by itself will never melt, being perfectly infusible, but it acquires the property of fusibility to a greater or lesser degree according to the quantity of the above metallic oxides with which it is mixed before undergoing the melting process. There are many formulæ published for the manufacture of glass, but as we shall see, not every kind is fit for optical purposes.

The word "glass" derives from the Saxon verb *glis-nian*

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* A commencement in this direction has been made in electroplating with silicium, obtained directly from quartz by means of hydrofluoric and hydrochloric acids. The metal silicium is invisibly suspended in the solution in which the article to be plated is immersed, and is set free by the action of a galvanic current. In this way we obtain a thin film of the real metallic base of quartz. An incandescent lamp has lately appeared in England in which the filament is coated with a layer of silicium and the degree of vacuum required inside the bulb, it is claimed, can be lessened. — When we consider how tedious were the first experiments with Aluminium, and in what quantity and with what facility this metal is now produced, we may also expect to see Silicium introduced sooner or later into the market as a new metal for ornamental or industrial purposes.

(the German *gleissen*), to shine, to be bright, and was by old writers frequently applied to shining or glittering substances, without reference to color or transparency. The combination of sand with an alkali (potash or soda), melted together, yields only the so-called *water-glass*, soluble in boiling water to a fine, transparent, semi-elastic varnish, used for the adulteration of soap; also for hardening mortar cements, etc., so as to render them impervious to water. An application of it to wood renders the same almost incombustible. But to produce a glass not to be affected by water and acids, it is necessary to add one or more of the metallic salts, such as barium, strontium, calcium, magnesium, aluminum, manganese, arsenic, or lead. Some of these facilitate the melting process, and are called *fluxes* or solvents, others serve as decoloring agents. The proportion in which the above substances are used, and the different compositions made by them in addition to the principal ingredients (quartz and potash) constitute the different kinds of glass. Although there is no secrecy of the most improved formulæ of making all kinds of glass, it is nevertheless a well established fact that one factory offers a better article for sale than others, because they take better materials, and their workmen are more careful and competent, as is the case in all other trades. It is almost impossible to obtain or even prepare the ingredients in a state of chemical purity previous to fusing them together.

SAND is always more or less impure, and must be carefully washed and cleaned. Many varieties of this material are not fit for the manufacture of glass. Only rock crystal and quartz are chemically pure, especially the first, but they require the extra expense of being pulverized. Formerly flint (silex), calcined and ground, was used as the source of the silica for the manufacture of fine glass; hence the name of *flint glass*.

POTASH and SODA* are used in a purified state only for the best qualities of glass, but crude potash and soda-ash are employed for the medium quality, while

* They are often combined, as their mixture acts more rapidly, and at a considerably lower temperature than either of them will separately.

common wood-ashes and refuse soda will do for bottle glass. The potash used for this purpose is the *carbonate of potash* (Salt of Tartar), and requires a process of washing previous to use. The state to which it is brought by the process of cleaning is that of fine white grains, differing but little, to an unpracticed eye, from the prepared sand. Other combinations of potassium, such as *nitrate of potash* (saltpeter), and *sulphate of potash* (alum), counteract the tendency to color, before the glass enters into perfect fusion.

LIME (calcium) forms an important part in the manufacture of glass, and may be introduced either slaked, burned or as a carbonate (chalk). Limestone, however, that contains iron, must be excluded from the mixture for making white glass. The action of lime is to promote the fusion of the mixture, and to make the glass hard.

LEAD is the distinguishing ingredient in crystal, common flint glass, optical glass and strass. It is used in the form of red lead or litharge, and removes many impurities as, for instance, charcoal by oxidation. An excess of lead induces too great softness in the glass, and gives a yellow tinge.

BARYTA (barium), in the form known as "heavy spar," is sometimes added to the constituents of common bottle glass to render it more easy of fusion.

ALUMINUM (clay), though seldom purposely introduced into glass, is always accidentally present, brought there by the action of the materials upon the clay of the pots in which they are melted. If present in any quantity it spoils the perfect crystallization of the glass.

IRON is another unwelcome element, which is almost always present in the sand, in the soda and in the chalk, and produces a greenish color in the glass when not removed.

ARSENIC, in little quantities, promotes the decomposition of the other ingredients, and tends to dissipate carbonaceous impurities not otherwise disposed of, but is then volatilized. In excess, it produces a milkiness in the glass, which time will increase.

MANGANESE is employed to neutralize the greenish

tint produced by the presence of iron, and to counteract the impurities of carbon. If particles of carbon or soot from the fire or flame become mixed and surrounded with the melted glass, these, by their exclusion from the access of air, are prevented burning, and a brown or smoky color is produced, which is removed by the conversion of the carbon into carbonic oxide through the oxidizing influence of manganese. (Arsenic and nitrate of potash are also used for the same purpose.) From the cleansing action of this material, it is generally termed the "glass-makers' soap." It must, however, be used sparingly; for an excess of it gives an amethystine tint to the glass. Such colored lenses are introduced into the market under the name of "Arundel."

BORAX is sometimes employed as a flux, but it must be used always with great caution, as an excess leads to exfoliation of the glass.

There are *four varieties* of glass manufactured, besides the above mentioned water glass:

1. *Flint glass*, also called *Crystal*, *Strass* or *Paste*. This is a very pure and beautiful kind of glass, of great density and high refractive power. It is properly termed lead-glass, since it is the presence of this metal which distinguishes it from all other varieties of glass. It is chiefly manufactured into articles of domestic use and ornament, and is an English invention.* The best formula of flint glass manufactured for optical purposes is:

| | | |
|---|---|---|
| 42.5 | parts of | silica or sand, |
| 43.5 | " " | oxide of lead, |
| 11.7 | " " | carbonate of potash, |
| 1.8 | " " | nitrate of potash, |
| 5 | " " | chalk. |
| 100. | | |

* Flint glass was known over three hundred years ago. There was as early as 1557 a factory of it in London, and English flint glass was considered the best in the market. But they never could make pieces of more than a few inches in diameter, suitable for astronomical purposes, till Fraunhofer astonished the world with a lens of almost a foot in diameter, which was set afterwards into a refractor for the observatory at Dorpat, in Russia, and is yet in use. The difficulty is that the great quantity of lead in flint glass cannot be equally distributed throughout the lens.

The flint glass well prepared is almost without color. It excels in brilliancy and in refracting power all other glass, and when well polished by the lapidary, is considered the nearest approach to the diamond; but it is soft and easily scratched. The specific gravity is 3.7, due to the great quantity of lead, while that of crown glass is 2.7, and of rock crystal only 2.6. Many opticians may have confounded density with hardness, and have made the same mistake as if they maintained, that dense and compact chalk was harder than light and porous pumice stone, although the hardness of the first is 1, and of the other 7. Density is the opposite of rarity, not of softness.*

2. *English Crown Glass*, *Plate* and *Window Glass*. Crown glass is also an English invention. It was introduced into the market in circular plates, from which particular form it received its name. It does not contain any lead, and is therefore much lighter than flint glass. It has gained its great reputation since the invention of achromatic lenses for telescopes and other optical instruments. As the value and beauty of this glass depend entirely upon its absolute limpidness, a most careful selection of materials, and a protracted and assiduous attention of the workmen are required. The difficulties in producing large, thick masses of this glass for optical purposes are greater to-day than the fabrication of similar pieces of perfect flint glass; because the melting process of the ingredients of crown glass requires a greater temperature than those of flint glass, on account of the absence of lead, and, by adding instead more alkali to increase the facility of fusion, it becomes liable to attract humidity, or as it is technically termed, to sweat, which would make it unfit for optical instruments. The best formula of this glass for our purpose is:

* The problem of the manufacture of good optical flint glass in *large pieces* was first solved by F. Guinand, a Swiss watchmaker, who joined Fraunhofer's establishment at Munich. Both kept the process a secret. The superiority of their glass is considered not to have been in the novelty of the materials or their proportions, but in the careful agitation of the liquid glass, while at the highest point of fusion; then in the cooling down of the entire contents of the pot in a solid mass, and afterward in separating unstriated portions by cleavage.

| | | |
|---|---|---|
| White sand | 120 | parts |
| Carbonate of potash | 35 | " |
| Carbonate of soda | 20 | " |
| Chalk or slaked lime | 20 | " |
| Arsenic | 1 | " |
| | 196 | parts. |

There are 55 parts of alkalies in 196, which is equal to 28%, against 12% in flint glass. The addition of chalk is very essential; it counteracts the effect of the excess of alkalies which would produce in the lenses a constant tendency to tarnish, by the deposit of a film of aqueous vapor, and would cause them in the space of a few years to lose their polish.

The name of *Plate glass*, or, as it should be termed, *cast-glass*, might be applied to any kind of glass in sheets. This beautiful kind of glass is formed by being cast upon a smooth marble table while in a liquid state, and is totally independent of the process of blowing. The principal consumption of plate glass is for mirrors.

*Window Glass* is also a crown glass of inferior quality, which is first blown at the end of the pipe into a large globe, then converted by a rapid rotatory motion into a cylinder, which is cut up in the direction parallel to its axis and flattened into a broad sheet. The materials employed for the manufacture of this glass are chiefly silica, soda and lime; no potash is used.

3. *Bohemian* or *Crystal Glass*. The coarser qualities of this kind of glass are analogous in composition to bottle glass. But the finer kinds are distinguished by their comparative freedom from color, by great lightness, and their very refractive nature, which renders them capable of resisting not only high heats, but sudden changes of temperature. Hence the value of this glass for chemical purposes, such as retorts, tubes, etc. Its lightness and the total absence of color cause it to be highly valued as table-ware, for costly windows, covering of engravings, and also for spectacle lenses. In the finer qualities of Bohemian glass, potash is substituted for soda. Its formula is:

Quartz in powder.................100 parts.
Carbonate of potash........... 60 "
Carbonate of lime............... 20 "

4. *Bottle Glass.* The materials for common glass bottles are coarser than for any other kind of glass, and consist of silica, lime, soda, oxides of iron and manganese. Economy is the chief object, color and appearance being of no moment. The colored sands are even preferable to white sands, because the oxide of iron, which colors them, performs the part of a flux. They do not require any washing or other preparation, and instead of soda, common wood ashes obtained from domestic fires will do, after they are sifted and dried before using. This glass is the hardest of all, but is the most impure and therefore useless for optical purposes.

We see from this list, that the dearer potash is used only for the better qualities of glass, and the cheaper soda for the inferior kinds. If either of them is employed too freely, it spoils the glass. You have perhaps made the observation, after having carefully cleaned a mirror or window, that soon there was a scum again covering the just brightened surfaces. A repeated rubbing readily removed it, only to reappear as soon as you ceased your efforts. The excess of potash or soda attracts the moisture of the air, and baffles your exertions. Don't laugh any more at people complaining that they can never clean their spectacles; the lenses may be manufactured of such defective glass.

There is another serious evil attending the excess of alkalies in glass; they gradually oxidize by the action of the atmosphere, causing the appearance of rain-bow colors. But when after a length of time the potash and soda are more and more absorbed from the surface, there is left only a thin film of oxidized silica of a milky appearance, such as you find on spoiled lenses, especially on watch glasses, which are mostly made of glass containing too much soda. Such lenses cannot be cleaned by any acids, or by any amount of rubbing with water. The only way to clean them is a gentle rubbing with Cosmoline, provided they are not too far gone.

I think it proper here to direct your attention to the

many so-called *inventions* of unscrupulous parties, introducing their wonderful discoveries as something of great importance, i. e. for their own pockets, not for the public. The only invention they have really made is the *high-sounding name* which they flourish ostentatiously before the eyes of the amazed public; then waiting eagerly for the rush of deluded buyers, as the picadores in the arena wait for the headlong advance of the bull, enraged by the waving of the red cloth. Such names as *Perfected*, *Improved*, *Brilliant*, *Arundel*, *Diamond*, *Medicated*, *Diamanta*, *Crystal*, *Parabolic*, etc.,* are still fresh in our memories, and the list will increase as long as there are enough dupes living to make such a humbug pay. — I hope nobody will misconstrue these remarks as if I were against lawful advertisements of a good article. There is a way of introducing goods which is perfectly honorable, provided such parties use their *own name* as a recommendation for the superiority of their spectacles. If Dick & Harry are competent opticians, and keep nothing but first-class goods, nobody can blame them for drawing public attention to the fine brands of "Dick & Harry's Optical Goods." Their success is due to their expert selections and superior judgment, and not to false pretentions.

It is, therefore, very important that every optician be well informed about the *different qualities of lenses*; he should be able to determine their various grades as readily as a jeweler is able to ascertain the karats of goods he is buying. Lenses of the *first quality* always contain more or less lead, the larger its quantity (to almost half its volume), the finer its lustre and beautiful sparkling. This kind is known to the trade as *extra white* flint glass, and cannot be distinguished from pebbles by simply comparing them together by look. It is principally used for opera glasses and other optical instruments.

The best method of comparing different lenses is to place them horizontally or flat between your fingers; by

* The latest fake is a Southern product, called "Crystallized Lenses." I think, the South has as much right to humbug people as the North and East of the U. S. Who will be the pioneer in the West? There is a general demand for such inventions.

holding the hand towards the light, you can see in the narrow open spaces between your dark fingers the different degrees of the color of these lenses better than by placing them on white paper. But most lenses sold for first quality are not the *extra white*, and cannot stand comparison with pebbles; the simple hand-test shows a grayish tinge when compared with them.

Lenses of the *second quality* are either of crown glass or the refuse of flint glass, and are of course less costly. If they are made of a clear, well finished crown glass, they are preferable to any flint glass, because they are harder, take a higher polish, and are for this reason more suitable for cataract lenses. The inferior kinds of crown glass are also used for spectacles of lower grades, but the lenses have a greenish tinge when examined edgewise, and are full of imperfections plainly seen when looked through at the sky. Such lenses seem to be filled with half transparent little particles of dust, due to the incomplete process of melting the sand.

The *third quality* is not always made of poorer glass, because many lenses from the better qualities are selected to be used as they were cast. We find, therefore, among them very often white lenses, but they are never ground, and seldom polished. Their cheapness is due more to saved labor than to less costly material. I could extend the list of the different qualities to fourth and fifth grades, when I look around among the stock in trade of peddlers and "street opticians," but I hope none of my readers will be caught selling such trash. It is true, the eye can stand a great deal of abuse, but the wearer of such spectacles will at last share the fate of a spendthrift: the one loses his fortune, the other, alas, his sight.

To detect other imperfections we have to hold the lens at an angle of 35° in good light. The reflected light will show the smallest bubble or scratch in or upon the glass. Another and better method is to hold the lens before the eye, and look through it at a window. (This test refers only to cx lenses.) We will see the object behind it dimly, and in lengthening the distance gradually, it will appear still dimmer, till at once we see nothing but the glary lens, — it is just in its focal dis-

tance. If we remove the lens beyond this point, the object is then clearly seen but reversed, because the rays have crossed in the focus; the upper rays are now the lower ones, and *vice versa*. This point where we see nothing *behind* the lens, is the most proper for detecting all imperfections *in* the lens.

I conclude this chapter with some suggestions of reform to my associates in the optical trade. Every merchant tries to buy as cheap as possible in order to meet competition on an equal footing. Our constant demand for lower prices compels the importers and jobbers to make a similar request to the manufacturers, who, of course, will produce inferior goods to satisfy the general pressure. The consequence is a gradual decline in the quality of goods. What we call to-day "first quality," but pay only one quarter of what we paid thirty years ago for it, is not the same article. I still have from that time lenses on hand of Nos. 21, 23, 25, 33, 45, 50, etc. (because I thought them necessary to be well assorted), which are yet as bright as new lenses. Since they have fallen in price, I am compelled every year to throw many lenses away, even among those just received from an importing house, because some show already traces of rain-bow colors, others even are corroded. In former years, the grinders always had great trouble to find the right quality of glass for optical lenses, but since they can dispose of all kinds of trash, they work up any stuff which never was manufactured for that purpose. Glass, barely good enough for table-ware or window glass, is turned into spectacle lenses, because they readily can be sold to one or the other party. If our importers themselves were scientific opticians, or had one in their employ to superintend this branch of their business, the general decline in the quality of lenses would have been prevented. They would have found it to their interest to always keep a stock of good lenses on hand, even if they had to provide themselves for the trade at large, for jewelers and peddlers, with imitations. At present it is impossible to find the genuine lenses made of real optical glass. I do not blame the importers alone, but confess that this state of

affairs is mostly our own fault. We made the great mistake of altogether disregarding our responsible position to assist mankind in the preservation of their precious eyesight with faultless glasses; we degraded ourselves to mercenary traders for the sake of gain.

I remarked before, that we should be able to classify the different grades of lenses as readily as the jeweler ascertains the karats of his gold. I myself experimented for years in analyzing the different qualities of spectacle lenses as to the quantity of lead, arsenic, clay, potash, soda and other materials used in their manufacture, but I succeeded only partially by tedious chemical processes, which are not yet of any practical value to the craft. I wish others would direct their attention to this highly important subject, and being more successful, will earn a deserved reputation by publishing their discovery.

## CHAPTER III.

### Merits and Defects of Pebbles.

For more than a hundred years after cotton began to be cultivated in America, its seeds were considered worthless, and on every plantation large heaps of this contemned stuff accumulated in the course of time, which the planter would have gladly given for nothing, if anybody had been kind enough to cart it away. To-day, the seed yields more profit to him than the cotton. *Pebbles* met with the same treatment. Neither the builders had any use for them, nor street-pavers; only mineralogists noticed them, and occasionally collected some specimens as cabinet-pieces. A few manufacturers of glass also used them for making an extra quality of flint glass, but millions of tons of this precious mineral were left unnoticed by those who are now eagerly searching for it. Since 1783, when Alexis Rochon, the first writer on pebbles, gave an unfavorable account of them, and condemned them as useless for spectacle lenses, all writers on the subject are against them. Listen to what a Doctor says:

"The only practical advantage of pebbles over glass is, that they enable us with all honesty to gratify persons who do not know what they want, but simply wish to pay more than the usual price, or more than their friends did for their spectacles."

Another says:

"Rock crystal, or Brazilian quartz, is also used, and is commonly known as *pebbles.* It has no advantage over glass, except in hardness; in fact, the opticians find it difficult or impossible to distinguish between them without a polariscope or a file. Many people, however, are not satisfied unless they have pebbles, or think they have them, for glass is very often sold instead." This

physician forgets that jewelers are also compelled to use touchstone and acid to test gold. Is gold, therefore, less valuable ?

I have frequently tried to find some information about pebbles; but being unable to discover any book or pamphlet treating this subject, either here or in Europe, I concluded to search for myself, and ascertain if there was anything in it to repay the labor. A superficial glance at them revealed their extreme transparency, and plainly showed that few spectacle lenses possessed that brilliancy which characterizes these crystals. I asked myself the question: Why should we abandon the natural, pure glass for an artificial substitute; the *reality* for an *imitation ?*

The genuine article has two striking advantages over glass which cannot be denied: its *brilliancy* and its *hardness*. The principal objection made against the use of pebbles is their *double refraction*; but this is seen only in thick pieces, when we look through their slightly inclined surfaces. Objects thus seen through polished planes of massive pieces appear double, which is not the case with thinner plates, like spectacle lenses.*

Since, therefore, double refraction will affect vision only in thick pieces and not in thin ones, what reason have opponents to prejudice the public against their use? Why not raise their voices likewise against the use of small quantities of arsenic, belladonna and other poisons ? for it is well known that large doses of them have deadly effects. On the contrary, they, as well as the most cautious and conscientious physicians, daily prescribe small doses of these poisons, with successful results.

This is the only serious objection ever made against pebbles, and I would think it too insignificant in comparison with their other high qualities, which give them a prominent place among all their competitors for spectacle

* "The double refraction of rock crystals renders them useless for optical purposes, and especially for the manufacture of spectacle lenses, and although the images do not appear double across such lenses in consequence of their thinness, and the manner in which they are used, it is nevertheless true that double refraction exists, and that it can cause considerable trouble to vision by weakening the retina, and producing fatigue of the accommodation, or even a kind of amblyopy."—Manuel de l'Etudiant Oculiste, par ARTHUR CHEVALIER. Paris, 1868.

lenses, to waste another word in their defence, if it were not my object here to settle the dispute definitely, and furnish all the points necessary to justify my honest, favorable opinion about them. The main object of my investigation was to ascertain if the eyes were fatigued sooner with pebbles than with glasses. I directed my attention especially to the general cause of our getting weary, and I found that it is the effect of *heat* which relaxes the muscles and produces the sensation of fatigue. Consequently, those lenses which will transmit the most light and, at the same time, the least heat to the eye, should be used for spectacles. The test which I made in this respect by means of thermometers, first in 1871, I repeated before writing this article. In order to make this test simultaneously with different lenses, I selected six thermometers which worked accurately together; then I took an *axis pebble*, a *non-axis pebble*, a *flint glass*, a *crown glass*, a *light smoked* and an *Arundel lens*, all of + 8. I made a slender frame-work to hold the lenses and the thermometers; then removing the thermometers from their casings, I placed them, one each, in the foci of the different lenses. To guard against any inequality in this test, I took a straight piece of sheet-iron, and had six holes punched out, all of the size of a silver quarter dollar, and fastened the lenses behind each hole so that the optical center of the lens was in the center of the hole.

I took altogether thirty-two observations, with the following result:

| | | | | |
|---|---|---|---|---|
| The smoked lens | showed | 78° | on the | average. |
| " crown glass | " | 81° | " | " |
| " non-axis pebble | " | 81½° | " | " |
| " axis pebble | " | 82° | " | " |
| " flint glass | " | 83° | " | " |
| " Arundel lens | " | 84° | " | " |

The lesson we may draw from these observations is that we should dispense with flint glass and all colored lenses, except smoked. Crown glass and pebbles are then left as the only rivals for spectacle lenses.

To thoroughly ventilate the question: "Shall pebbles be used or not," it is necessary first to have a full un-

derstanding of the properties of crystals in general, and then to consider the difference between axis and non-axis pebbles. — Crystals are divided into: *Single* refracting crystals, such as rocksalt, alum etc., and *double* refracting crystals, of which we have two kinds:

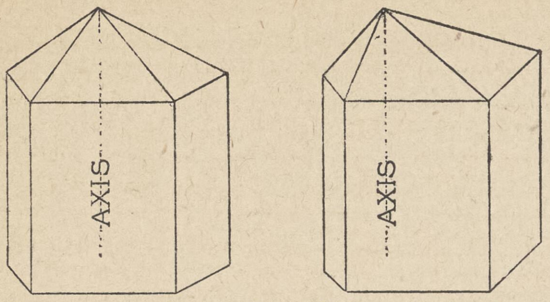
1. those with a single optic axis, as Iceland spar, rock crystal, tourmaline, beryl, etc., and

2. those which possess two optic axes, as feldspar, mica, topaz, etc.

When we take a plate or slab of a double refracting crystal with the single optic axis, for instance, Iceland spar, we see the object through its axis single; but when we hold it obliquely, the object appears double. We see then two distinct pictures, one produced by the *ordinary* ray which shows the object single when we look through its axis, another object by the *extraordinary* ray, separating itself from the first one, the more so when gradually we incline the surface of the crystal towards its equator, or perpendicularly to its axis. This is called the *double refraction* of a crystal. The two objects separate from or approach to each other, according to the position of our eye towards the equator, or towards the axis of the crystal. But when we turn the inclined crystal around its equator, from right to left, or from left to right, keeping the position of its poles unchanged, then the extraordinary image of the object rotates around the ordinary one without altering the relative distance to each other. As *pebbles* belong to this class of crystals we make a memorandum of their first property: *A pebble has no double refraction in its axis.*

Let us now determine what is an *axis*, and what is a *non-axis* pebble. Rock crystals are six sided prisms terminated by six sided pyramids.

The dotted line from apex to base of the pyramid, parallel to the sides of the prism, indicates the *principal axis* of the crystal. It is evident that this axis is not always in the middle, but very often to one side of the crystal according to the position of the apex. Lenses cut at right angle to the axis from crystals where *the principal axis is in the center of the column*, will show in the polarizer (tourmaline plates) perfectly shaped colored




rings whose center is in the middle of the lens. But when the apex is at one side, all lenses cut in the same manner of such crystals will show the prismatic colors only at one side of the lens and generally very faint and imperfect. Lenses cut at right angles to the principal axis are called *axis pebbles*. In case the lenses are cut in any other direction, such lenses are called *non-axis pebbles*, and do not show between the tourmaline plates the rainbow colors. If any one of my readers will examine his stock of axis pebbles, he will be astonished how few perfect lenses there are among them, perhaps not one in a hundred. All talk about the preference of axis pebbles is, therefore, imposition, because they are not in the market. But suppose they were manufactured according to scientific principles, and could be bought even at a great increase of price on account of the few perfect crystals found, would it be worth while to bother ourselves about them ? Let us see what double refraction in pebbles amounts to. The greatest power in this respect is in Iceland spar, and plates of it for experimental purposes are generally one inch thick, in order to show their action to some advantage. The thinner these slabs, the less will be their action. A plate of one line (or the twelfth part of an inch) will have very little effect. To produce the same effect as such a thin plate of Iceland spar will have, we must take one of rock crystal 115 times as heavy, which would be a lens of 10 inches thick.

Is it not ridiculous to warn people of double refraction in pebbles ? We could with equal right warn them not to breathe, because there is carbonic acid in the air. (One molecule of air contains .79 nitrogen, .21 oxygen and .0004 carbonic acid).

And so we make another memorandum to the credit of rock crystals: *Double refraction in pebbles is perceptible only in very heavy plates.*

It now remains to compare pebbles with crown glass and see in whose favor the scales will turn. Crown glass, as we have seen in the preceding chapter, is a hard glass, sufficiently clear for optical purposes, but it shows edgewise a greenish tint. Some manufacturers produce a crown glass without this tint by adding during the melting process, arsenic and manganese in greater proportions than usual, which do not interfere with the hardness of the glass, as lead would do, but favor its early corrosion. If it is made according to the best formula, the index of refraction is 1.538, and the index of dispersion 0.037, while flint glass has an index of refraction of 1.633 and of dispersion 0.049. When we take into consideration that a greater index of refraction dazzles the eye more than a lower one, and a greater index of dispersion annoys and fatigues the eye, we understand at once why crown glass is superior to flint glass for spectacle lenses.

As regards pebbles, we have to notice their slightly greater index of refraction (1.548), which accounts for the higher stand of the thermometer in the trial-test. The difference in the refraction of crown glass and pebbles is very small and is fully balanced by the lower index of dispersion, which is only 0.026 in pebbles. The difference of the thermometer between axis and non-axis pebbles puzzled me at first considerably; but I think it can be fully explained by the presence of the prismatic colors in axis pebbles. The red ray is very predominant in such lenses, and as the *red* is the caloric ray "par excellence," it explains the greater heat in comparison to non-axis pebbles. I believe this also covers the case in regard to Arundel lenses, which are based altogether upon a wrong theory. When we resolve the light by a prism into its seven colors and examine the caloric of the violet ray, we find it of much lower temperature than that of the red ray.*

* Herschel found the following degrees of heat in the different colors of the spectrum :

| | | | |
|---|---|---|---|
| Violet | 54° | Yellow | 62° |
| Blue | 56° | Red | 72° |
| Green | 58° | Beyond Red | 79° |

But when we produce a *violet lens* and let the light pass through it, the red ray receives an additional force from the reddish tint of the lens, which sends a warmer light to the eye than white glass does. In the spectrum, the violet ray is isolated from the other rays and is, therefore, cooler; but a *violet lens* does not exclude the other six colors. Hence, we cannot expect the same loss of temperature, which depends upon the *isolation* of the ray and not upon the *color* of the lens.

The prejudices against the use of pebbles for spectacle lenses are of such long standing and are so deeply rooted in the minds of many oculists and opticians, that I do not expect to have removed all objections raised against their usefulness. I am far from representing my opinion to the craft as infallible; I content myself with the conviction of having done my duty in disenchanting the "Sleeping Beauty" and in defending the rights of a neglected "Cinderella." My arguments are like a wet sponge, clearing this natural, genuine glass from the dust of a century, and enabling it to prosecute its own case with the prospect of gaining it before an unbiased court of investigation. Its hardness and clearness surpasses any glass ever offered to take its place; its dispersing power is the lowest of all lenses manufactured for optical purposes, and its double refraction is practically harmless: who dares to throw a stone at my humble supplicant for recognition?

Pebbles are particularly fitted to correct cases of presbyopia and hypermetropia, because the eyes subjected to these deficiencies are rather benefited by the slightly increased index of refraction, while the less refracting crown glass is preferable for myopia and cataract. Pebbles are too glary for a near-sighted eye and may show traces of double refraction in thick, heavy cataract lenses. Eyes, sensitive to light, should also abstain from using pebbles; only light smoked lenses and, in special cases, light blue ones can be used with satisfaction. The light blue tint has no disagreeable effect, and is almost indifferent to the feeble eye.

In closing this chapter, I express the hope that other writers may investigate the subject and at last free this

"out-cast" from the odium of being a disguised enemy to the eye. As far as I have investigated the matter, I find that all the ignorance of thoughtless writers heretofore has not been able to rob these crystals of their hardness, nor to obscure their brilliancy and clearness. All insinuations about their double refraction have been unable to double the finest test-line or dot in spectacle lenses of this mineral, or to produce the great trouble in the eyes of the wearer which they so earnestly predicted. Pebbles are used to-day and will be used in the future as long as rock crystals can be found. I advise all opticians to sell them without the least hesitation, but to dispose only of those lenses which are faultless as to their crystallization. There are many pebbles in the market full of imperfections, so-called "water marks"; they should not be used, but thrown aside.

Lenses of rock crystals were first introduced in England under the name of Scotch pebbles, and afterwards as Brazilian pebbles, which designation only indicates the country from where they are imported and not a difference in the quality. Crystals are found all over the world, but not everywhere in large pieces suitable for our purpose. Rochon discovered in Madagascar a fine quality of crystals, and ever since large quantities of them are brought to France, where the optician Canchoix at Paris, 1831, manufactured telescopes with lenses of a combination of rock crystals and glass, which came into favorable notice. But the difficulty of obtaining crystals in proper shape and size has been a great obstacle to their general manufacture.

Many peasants of the Valley of Chamounix, Switzerland, make it their chief occupation to hunt for rock crystals. In the hope of gaining sudden wealth by finding a cave full of beautiful rock crystals they peril life and limb in scaling dangerous precipices, or hanging suspended over frightful abysses, searching wherever they may catch a glimpse of the silver-white vein in the granite rock, the sign that near by is a deposit of this precious mineral. A Swiss peasant, some years ago, realized his hope; he found a granite cave from which he took over one hundred crystals, the first weighing about 120 pounds.

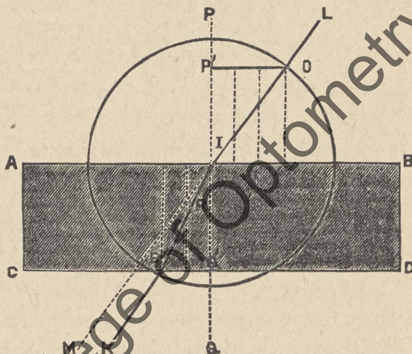
This was brought to America, and is at present in Philadelphia; another one of 265 pounds was kept at Berne, the Capital of Switzerland, but is not as fine a crystal as the one first mentioned. The largest groupe of rock crystals, weighing nearly 1000 pounds, is in the museum of the University at Naples. At Milan is a single crystal of $3\frac{1}{4}$ ft. long and $5\frac{1}{2}$ ft. in circumference, estimated to weigh 870 pounds.

In the United States some rich deposits have been met with at Lake George and at Trenton Falls, N. Y., in Moose Mountain, N. H., in Waterbury and Windham, Vt., in Hot Springs, Ark., and in other places.

## CHAPTER IV.

### PRISMS, SPHERICAL AND CYLINDRICAL LENSES.

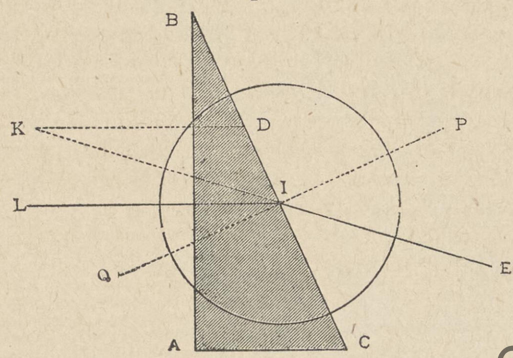
The most simple glass used for spectacles is the PLANE, both sides of which are parallel, forming a slab or true plate. Light passes through it without any refraction, provided it strikes the surface at right angles to its planes. As soon as we incline the slab so that the light falls on it obliquely, the light no longer follows its straight course but is bent more or less, according to the quality of the glass of which the slab is made. This inherent power of any glass to refract a ray of light in a certain proportion is called its *index of refraction*. Crown glass, for instance, has an index of about 1.5, and as air is taken as the unit (Chap. XIII), we express its formula by $\frac{1.5}{1} = \frac{3}{2}$, the correctness of which may be demonstrated by an experi ment illustrated in the following diagramm:




The incident ray *l* is intercepted by the crown glass *a b c d* at *i*. When we raise the perpendicular *p q* and divide the distance between this and the incident ray *l i* at the height above the slab equal to its thickness into three parts and at *e*, the point of the exit of the ray, into two parts, then we have the *direction* the ray will

take through the slab. At *e* it will again enter the air parallel to *l i*, but not in its exact prolongation which would be at *m*; it is now by the refraction of the slab slightly shifted or displaced in the direction of *e k*.

If we cut the above slab in the direction from *b* to *c*, we obtain two triangular wedge-shaped pieces of glass, called PRISMS. In directing the side of one of these prisms, say *a b c*, perpendicularly to the incident ray, this ray will enter the glass in a straight line till it reaches the oblique side *b c*, when it will be bent in the same manner as the oblique ray was refracted in the slab. In a slab it is the oblique *ray* that produces the effect which in a prism is due to its oblique *side*.

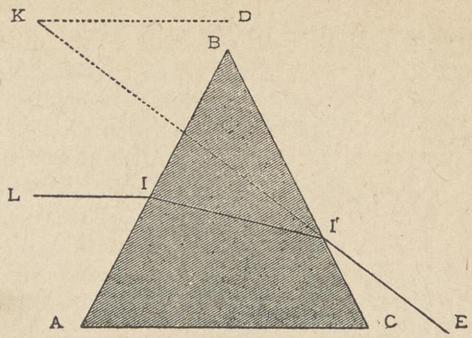



The ray *l* enters and penetrates the prism in a straight line until it touches *i*, where we erect the perpendicular *p q* upon *b c*, then we divide the distance between the incident ray and the perpendicular at *q* into two equal parts, when three parts of them from *p* downward (toward the base) will show the direction the ray has taken outside the prism. If we place our eye at *e*, the object *l* appears at *k*, as if it was removed from *i* to *d*.

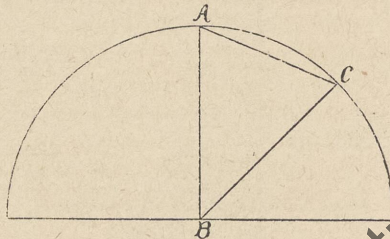
When we hold the prism in such a position that the incident ray falls on it obliquely, the ray is first broken in the prism itself and then by the second inclined surface.

The object at *l* appears now to be displaced outside the prism.

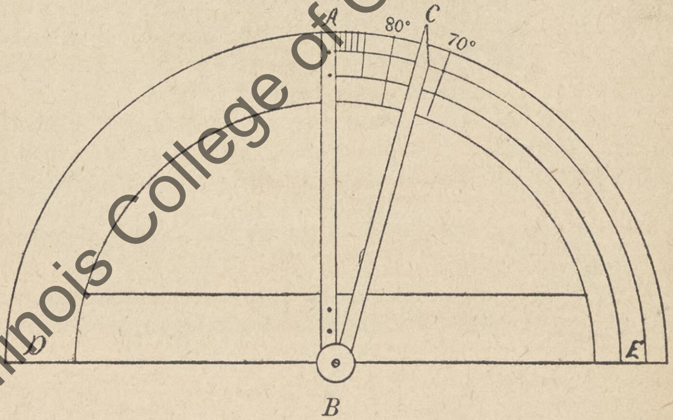
Prisms have no focal power like spherical lenses, and cannot be measured by inches; their strength is simply




determined by the angle at *b* in degrees. Its opening at *b* confers upon the prism its strength and name. We have prisms of 1°, 2°, etc. The following figure represents a prism of 45°, or the eighth part of a circle.




With a "trial box," containing test prisms, the strength of a prism may be determined by neutralizing it by another; but to ascertain also the correctness of our test-prisms, it is necessary to construct a tool made of a *protractor*, like the following.



The joint B must be exactly in the center of the semicircle D A E. That side of the riveted or stationary bar A B which is nearest E, is precisely 90° from either D or E. The arm B C is movable, and indicates the number of degrees of a prism placed in the opening A B C. * I present also another easy way of testing prisms by the use of a simple ruler.

Take a ruler of 12″, American measure; cut a notch in the edge at $6\frac{1}{2}$ inches, large enough for the reception of the base of the prism. Place the longest part of the ruler on the line A B, and lay the base of the prism in the notch, so that the line A B is not broken in the prism; then see how far towards the right the line C D is displaced, and you will find that each degree represents $\frac{1}{16}$ of an inch; a prism of 16° displaces the line C D, therefore, exactly one inch. It is quite immaterial

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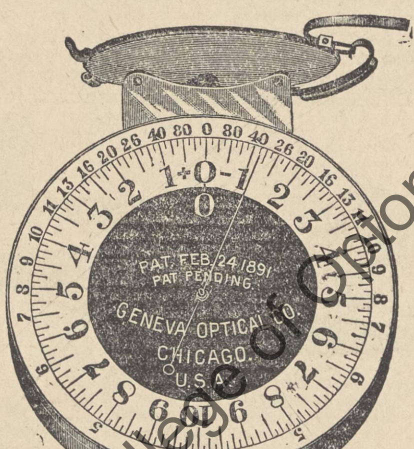
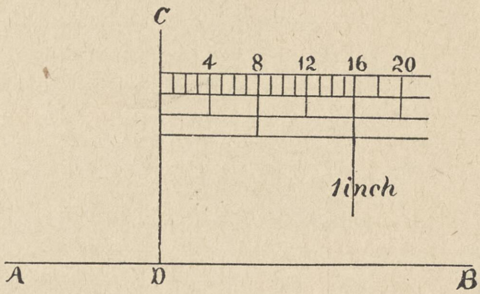
* Last year, the Geneva Optical Company introduced a new device for centering lenses and measuring the degrees of prisms. It is based on the principal of the above protractor, but is more practical and easily handled. They also introduced a novel lens measure which is based on




the refractive power of flint glass. It accurately measures not only convex and concave lenses, but also cylindrical lenses and enables us to readily find the axis of the cylinder. This little instrument will become very popular among oculists and opticians who are not experts in measuring compound lenses by the regular analytical method.

4

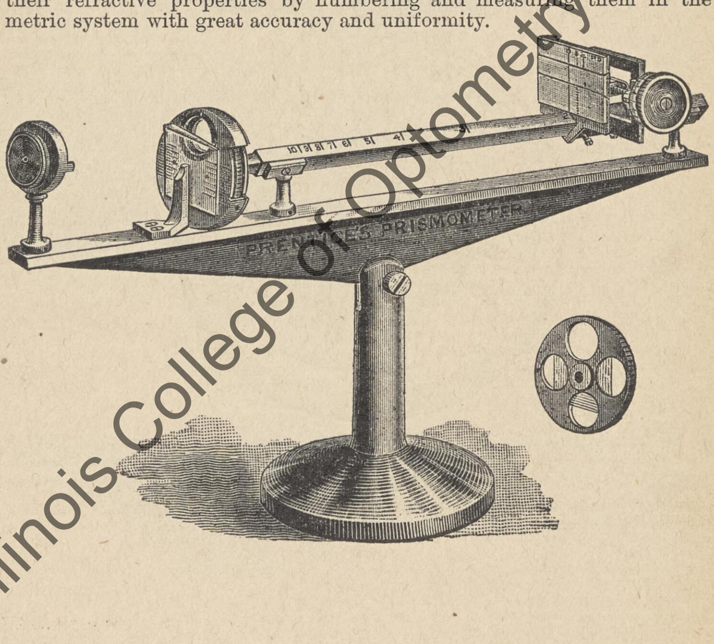
how near or far we place our eye, as the deflection of the prism is not altered by it.*

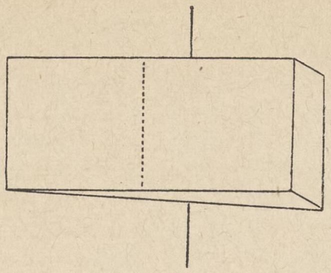



The following diagram represents a prism of 4°; the dotted line shows the displacement of the object looked at through the prism of that strength, held six inches and a half from the test-line.

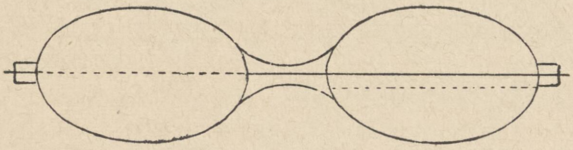
The thicker end of the prism is called the *base;* and "base in" means to place this end towards the nose-piece

* This scheme is most skillfully brought into a scientific system by the invention of Chas. F. Prentice. His *prismometer* is an ingenious instrument; it does away with the heretofore crude method of numbering prisms by the angular deviation of their surfaces, in making use only of their refractive properties by numbering and measuring them in the metric system with great accuracy and uniformity.

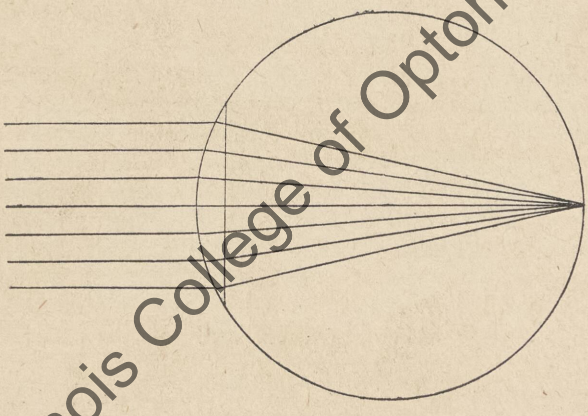




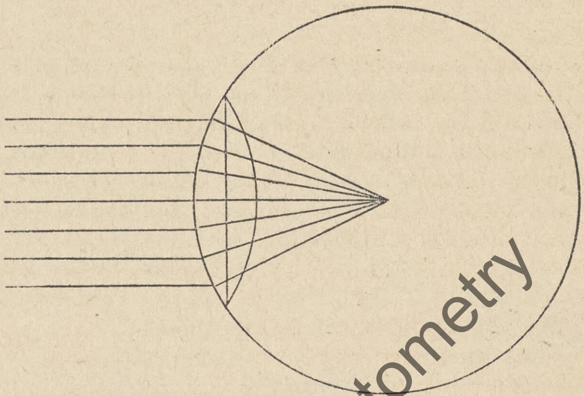
of frame. In setting such glasses, care should be taken that a straight line is not broken in either of the lenses.



If we take two prisms of the same strength, and lay them together so that the thick part of one covers the thin part of the other, we shall have a plane glass; one neutralizes the action of the other. The peculiar action of a prism consists simply in the *displacement* of an object seen through it. The object never appears where it really is; it is seen higher or lower, or more to the right or left than it should be. This is due to the different positions in which the prism is held. The dotted lines show the defective setting of one prism.



SPHERICAL lenses, as we have seen in Chapter I, are ground by a segment of a sphere (globe or ball), imparting to the lens the same curve, so that the finished lens itself is but a segment of a ball, and subject to the general laws of refraction. Any transparent sphere has its focal point just * at that part of its periphery which is opposite the entrance of the ray, and if we substitute for the ball one of its segments, which will be here a plano convex lens, the focal distance is not changed. If this ball is of 2″ diameter, then the segment is of a 2-inch focus, or as we write it, to express the refractive power, $+ \frac{1}{2}$. But if we double this segment, then the focal point lies in the center of the ball, and its strength is one inch focus, or $+ \frac{1}{1}$, equal to the unit of refraction in the inch system of numbering.



This rule is good for lenses of any other number, because the relative strength of a lens is constituted by the curve alone, and not by the thickness or thinness of the material of which it is composed. The two opposite curves can be widened by several plane glasses, put between them, without altering the focus, provided we do not change the place or position of the lens nearest the focus, and only widen the outside half of the double lens. For instance, take two + 8-inch periscopic lenses, put the hollow sides together, and measure this double

* "This is strictly speaking only true when the refractive index is 1.5." (CHAS. F. PRENTICE.)

lens; you then have a lens of focus + 4-inch. Hold the inside lens steady and remove the outside lens ¼ inch, and the focus is not visibly altered.

When we hold a spherical lens vertically in our left hand, and, with our right fingers, turn it around its center, without moving our left hand, we see no change in the object we are looking at. The movement around its center has no action on the object seen through the lens; it is the same as if the lens were held steady, and not moved at all. This should be remembered, because it is essentially different from the action of prisms and cylindrical lenses.

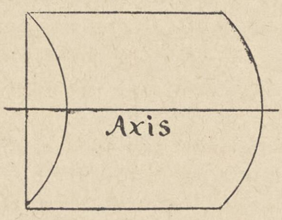
Manufacturers of optical instruments make use of this peculiarity in testing the correctness of lenses. They glue them upon a chuck of the turning lathe, and place a light at some distance in front. If the lens is well centered, the light will appear in the lens perfectly steady when the lathe is set in motion; otherwise a glary circle will be visible in the lens. The larger the circle is, the more the lens is decentered; and it is only after its true center has been correctly determined, that the workman finishes the edges. All lenses of opera glasses, telescopes, etc., receive their finishing touch in this way on the lathe.

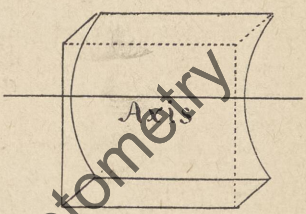
We have already learned that prisms have the power of displacing an object without altering its size, and that their strength corresponds exactly with the degree of displacement of the object. With spherical lenses it is quite different; they enlarge the object when they are convex, and diminish it when concave, but leave the position of the object unaltered, except in special cases to be explained in the next chapter.

If we consider a spherical lens to be but a concentration of innumerable minute prisms, with either "base in" when convex, or "base out" when concave, and also bear in mind that in prisms the incident ray is refracted towards the base: then we shall at once understand why convex lenses unite or converge the rays to a plus or *positive focus*, and concave lenses diverge them to a minus or *negative focus*.

CYLINDRICAL lenses are ground and finished with a

cylinder, instead of the segment of a ball used for grinding spherical lenses. When the outside of the cylinder is employed, the lens will be concavo-cylindrical; but when the concave side of a section of the hollow cylinder is used, the lens will be convex-cylindrical. The size of the cylinder imparts to the lens its strength; for instance, a cylinder of 5″ diameter will produce a cylindrical lens of 5-inch focus, or of 8 D. Properly speaking, there is no common focus or focal point to a cylindrical lens, but instead thereof a focal *line* which is parallel to its so-called *axis*. We find here again an analogy to the properties of prisms. While in spherical lenses the prisms encircle a common center or focus, they are in cylindrical lenses arrayed with their bases when convex, or with their apexes when concave, in a straight line across the lens, called the axis. We may say, therefore, that the fundamental forms of all lenses are but *modified compounds of prisms;* even the simple slab is a double prism, as we have seen at the beginning of this chapter.



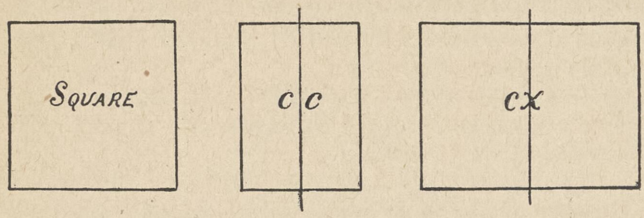




The axis of such a lens passes along the highest or lowest ridge of it, and is easily determined by moving the lens up and down, and finding by its gradual turning that line where there is no action at all. As long as the object seen through the lens moves with the motion of the lens, the axis is not yet found.

The peculiar action of cylindrical lenses, producing an apparent lengthening or shortening of the object, alternately looked at through a convex and concave cylindrical lens, is best shown by the changed form of a square.

A convex-cylindrical lens with axis vertical will lengthen the horizontal sides, producing a horizontal parallelogram. A concavo-cylindrical lens similarly placed, will have the opposite effect, making the paral-

lelogram vertical. This explains why a convex and concave cylindrical lens of the same power laid together,




axis upon axis, will counteract each other, and restore the parallelogram to a perfect square. When we take two cylindrical lenses of the same strength, and place the axis of one *vertically*, and of the other *horizontally*, we destroy all cylindrical action, and retain only the strength of a simple *spherical* lens of the same number or power as that of the cylindrical lenses. Take, for instance, two lenses of — 2*c*, lay their axes crosswise, and you have — 2*s*, which is neutralized by + 2*s*. But, if we lay the two lenses (— 2*c*) axis upon axis, we *double* their power in getting a lens of — 4*c*. — My first experience with these lenses was about twenty-five years ago; they were the plano-cylindrical, and their axis was set either in the vertical or horizontal meridian. I soon tried to combine the cylindrical with a spherical lens, gluing them together with Canada balsam, till I was advised from Berlin and Paris, that both corrections were ground upon the same lens. Of course, American opticians were promptly up to their profession, and since several years all combinations are ground here. Many blunders were made from all sides, and it seemed almost as if this new departure was a failure, till Nachet, and afterwards other opticians, improved the trial-frame. Yet, there was only a limited number of opticians who worked with the full understanding, and were able to convert one combination into another. As to my own researches, I must say that it took me a good while before I found the practical method of making this conversion with certainty.

My simple process is based upon the above three *fundamental laws*; let us bring them into such a shape that they will be remembered forever when once thoroughly

understood. By means of these rules we can turn cross-cylinders into sphericals and compounds, and again into cross-cylinders without any trouble or error.

I. Plus and minus cylinders of equal strength, and at same angles, *neutralize:*
$+$ 1*c* axis 90° ◯ — 1*c* axis 90° = a plane.

II. Two cylinders of equal strength and denomination, at same angles, *double:*
— 1*c* axis 180° ◯ — 1*c* axis 180° = — 2*c* axis 180°.

III. Crossed cylinders of equal value, produce *sphericals:*
$+$ 1*c* axis 90° ◯ + 1*c* axis 180° = + 1*s*.

The first two laws coincide with the properties of spherical lenses and need no further explanation, but the third law throws a new light upon sphericals; it demonstrates the fact that spheres are only crossed cylinders, of which the proof is easily made. We know that + 2*s* is neutralized by— 2*s*; we also know that the crossed cylinder

— 2*c* axis 90° ◯ — 2*c* axis 180°, = — 2*s*,

and that the concave sphere (— 2*s*), or those concave cylinders combined, will turn + 2*s* into a plane or slab. Now, instead of placing both cylinders *at once* upon the convex lens, we may take the first one at 90° and lay it on the spherical lens. I wish, the reader would make here this experiment for himself, as it is of the greatest interest to notice practically the changes gradually brought about in the spherical lens by the addition, first of one and then of the other cylinder. As the lens — 2*c* axis 90° represents only one half of the power necessary to neutralize the test-lens, its application to the spherical lens is quite singular, as it totally alters the nature of the sphere by turning its non-corrected half into a distinct convex cylinder axis 180°, which is fully neutralized only by the addition of the second concave cylinder at the same angle [180°].

There are two combinations of crossed cylinders:

1. Both cylinders have equal signs, but one is stronger than the other. For instance: + 2*c* axis 90° ◯ + 1*c* axis 180°; this crossed cylinder can be converted into the following compounds:
$+$ 2*s* ◯ — 1*c* axis 180°, or + 1*s* ◯ + 1*c* axis 90°.

2. The cylinders have mixed signs, no matter how strong each cylinder.
   $+ 2c$ axis 90° $\bigcirc$ — $2c$ axis 180°; their equivalents are: $+ 2s$ $\bigcirc$ — $4c$ axis 180°, or — $2s$ $\bigcirc$ $+ 4c$ axis 90°.

To come to the above answers, we have to turn one of the cylinders into a spherical lens, making use of the third law. For instance: $+ 2c$ axis 90°, requires the cylinder $+ 2c$ axis 180° to turn it into $+ 2s$; but then we have to neutralize this first addition by — $2c$ axis 180°, in order not to alter the original strength of the crossed cylinder, although we have changed entirely its form. Thus:

$$\begin{array}{llll} +2c \text{ axis } 90° & \bigcirc +1c \text{ axis } 180°; & \text{by adding} & \\ +2c \text{ `` } 180° & \bigcirc -2c \text{ `` } 180°, & \text{which is a plane, we receive} & \\ \hline +2s & \bigcirc -1c \text{ axis } 180°, & \text{the first answer.} & \end{array}$$

We take the same crossed cylinder, and turn the second one into a sphere.

$$\begin{array}{lll} +1c \text{ axis } 180° & \bigcirc +2c \text{ axis } 90°; & \text{we add} \\ +1c \text{ `` } 90° & \bigcirc -1c \text{ `` } 90°, & = \text{plane, and we get} \\ \hline +1s & \bigcirc +1c \text{ axis } 90°, & \text{the second answer.} \end{array}$$

Remember that each time we added something to the crossed cylinder in the problem, this *something* represented only a plane or slab, according to the first law, although it was really a crossed cylinder in disguise; but it completely changed the nature of the test lens, which a plane glass cannot do.

Let us now see about the second combination with mixed signs, by making use of the same process.

$$\begin{array}{lll} +2c \text{ axis } 90° & \bigcirc -2c \text{ axis } 180°. & \text{We again add} \\ +2c \text{ `` } 180° & \bigcirc -2c \text{ `` } 180°, & = \text{a plane, and get} \\ \hline +2s & \bigcirc -4c \text{ axis } 180°, & \text{the first answer.} \end{array}$$

We now turn the second cylinder into a sphere:

$$\begin{array}{lll} -2c \text{ axis } 180° & \bigcirc +2c \text{ axis } 90°, & \text{adding} \\ -2c \text{ `` } 90° & \bigcirc +2c \text{ `` } 90°, & = 0, \text{ we come to} \\ \hline -2s & \bigcirc +4c \text{ axis } 90°, & \text{the second answer.} \end{array}$$

To turn a compound lens into a crossed cylinder, we make use of the same experiment of which I spoke at the beginning of this article. Let us take the last answer:

— 2*s* $\bigcirc$ + 4*c* axis 90°, and add
+ 2*c* axis 90° $\bigcirc$ — 2*c* " 90°, = 0, we get

— 2*c* axis 180° $\bigcirc$ + 2*c* axis 90°, a crossed cylinder.

The first cylinder of this answer [— 2*c* axis 180°], may puzzle the inexpert, but Law III explains it quickly. We can neutralize — 2*s* either by + 2*s*, or, as we did in the problem, by the crossed cylinders:

+ 2*c* axis 90° $\bigcirc$ + 2*c* axis 180°.

By laying + 2*c* ax. 90° on the test-lens, the remainder of it ought to be a cylinder which is neutralized by + 2*c* axis 180°, according to Law I.

As I used in the foregoing problems the most simple values and always the same numbers, let us now select a problem with varied numerals as a further illustration. For instance:

+ 1.75*c* axis 90° $\bigcirc$ — 2.50*c* axis 180°. To turn the first cylinder into a spherical, we must combine it with + 1.75*c* axis 180°; then we have to add — 1.75*c* axis 180°, in order to neutralize the first addition, thus:

+ 1.75*c* axis 90° $\bigcirc$ — 2.50*c* axis 180°
+ 1.75*c* " 180° $\bigcirc$ — 1.75*c* " 180° = plane

+ 1.75*s* $\bigcirc$ — 4.25*c* axis 180°, or

+ 1.75*c* axis 90° $\bigcirc$ — 2.50*c* axis 180°
+ 2.50*c* " 90° $\bigcirc$ — 2.50*c* " 90°

+ 4.25*c* axis 90° $\bigcirc$ — 2.50*s*.

I will direct your attention now to the important question: "Is there any essential difference between a crossed cylinder and its equivalent compound?" Apparently there is a great difference, and yet there is none whatever; every compound lens is a crossed cylinder, and every crossed cylinder is a compound lens. Let us turn, for argument sake, the following crossed cylinder into a compound lens:

+ 1.50*c* axis 90° $\bigcirc$ — 2 *c* axis 180°; by adding
+ 1.50*c* " 180° $\bigcirc$ — 1.50*c* " 180° = 0, we get

+ 1.50*s* $\bigcirc$ — 3.50*c* axis 180°.

Now, let us turn the compound lens again into a crossed cylinder. In order to do this according to previous rules, we substitute for the spherical part of that

lens ($+ 1.50s$), its equivalent, viz. $+ 1.50c$ axis 90° $\bigcirc$ $+ 1.50c$ axis 180°, thus:

$+ 1.50c$ ax. 90° $\bigcirc$ $+ 1.50c$ axis 180° $\bigcirc$ $- 3.50c$ ax. 180°.

This formula, as it stands, is nonsensical, because we have only two surfaces on a lens for cylindrical corrections; but by looking at it critically, we observe that $+ 150c$ axis 180° $\bigcirc$ — 3.50 axis 180°, is only *one* cylinder of $- 2c$ axis 180°; and the actual formula of that triple cylinder, therefore, is $+ 1.50c$ axis 90° $\bigcirc$ $- 2c$ axis 180°, which is the crossed cylinder we first turned into a compound lens, and then again into its first form.

This practical test evidently demonstrates the fact that two faulty meridians in the eye, when 90° apart, are corrected as well by a compound lens as by crossed cylinders. But as cross-cylinders require greater care in grinding and fitting, all competent oculists and opticians prefer to substitute compounds, as being less liable to mistakes, and accomplishing the same visual correction.

About the year 1850, a French optician, Galland de Chevreux, introduced crossed cylinders instead of sphericals, claiming that they not only corrected presbyopia, but also the small degree of astigmatism with which nearly every eye is afflicted. A careful comparison of them with spherical lenses will show the fallacy of his claim. This, and their high price, have brought them into disuse. "In fact, it has been demonstrated, both by exhaustive mathematical calculation and experiments, that all crossed cylinders, for all deviations of their axes, may be replaced by sphero-cylindrical lenses".*

The use of cylindrical glasses has increased lately to such an extent that no optical establishment comes up to the requirements of the trade without being able to fill correctly the orders of oculists. One-tenth of all eyes are more or less astigmatic; and since oculists have taken the selection of spectacles in hand, the demand for cylindric glasses is very great.

* "We further are to suspect error in our estimation of the refraction of an eye seeming to demand cylinders combined under acute or obtuse angles." Dioptric Formulæ for Cylindrical Lenses, by Chas. F. Prentice, New York, 1888.

# CHAPTER V.

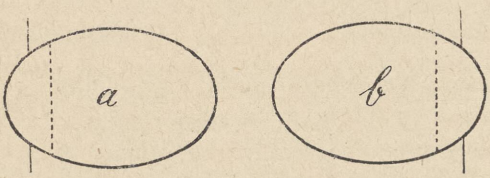
## Optical Line and Center.

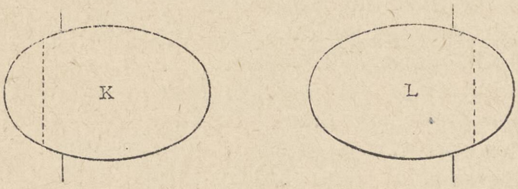
About twenty-five years ago, a traveler for a New York manufacturing house, offered spectacles for sale which he called "Perfected." When I asked what he meant by it, he said that the lenses were correctly set, the frames well tempered, and the whole spectacle *perfect*. To my great surprise, one lens of the first pair I examined was badly centered. He excused himself by saying that he was not an optician, he only represented the goods according to instructions given him by his employers, and promised that all goods I might order through him should be without fault. He admitted further that no member of his firm was a practical workman, but that the factory was superintended by a competent optician. Now, if this foreman really understood the meaning of an optical center in a lens, why did he not instruct the glass-setters how to be exact in the fitting of lenses to the frames, especially of those "Perfected Spectacles," for which they charged $4.00 a dozen more than for other goods not stamped, but of the same style and quality? I know not whether this name was invented only for the sake of extortion, or whether they charged so much more for the stamping of the temples, which was, indeed, nicely done in gold letters, and was something new at that time.

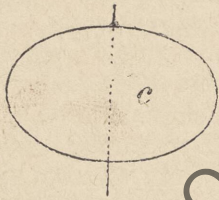
To be able to readily determine the *optical line* of a lens, is more important for an optician than any other acquirement of his trade. It is the essential requisite for the correct manufacture of all optical instruments, — spectacles, opera glasses, telescopes, or microscopes; the optical center must have its right place and position, or the instrument will be incorrect and worthless.

The best way to find this *center* is to look through the lens at a well-marked vertical line, drawn with pen and

ink and a ruler on a sheet of paper. Hang this paper against the wall some four or more feet from you; then take the lens between the thumb and first finger, extend your arm, shut one eye and look through the lens at that line. You will observe that the line is broken in the lens, and the more so, the nearer you move the lens towards its border. Figures *a* or *b* represent this phenomenon in concave lenses, and *k* or *l* as seen in convex lenses.



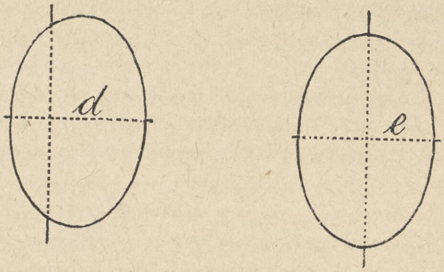




Now, move the lens slowly towards the center till you find the line unbroken, as in figure *c*; mark this line with ink, and it will indicate the optic line of the lens in one direction. Then turn the lens 90°, so that the line on the paper and the mark on the lens form right angles. Proceed in the same way as before, and you will find, very often, that the optic center is not always in the middle of the lens, as we see in figure *d*.

The two lines should cross each other in the middle of the lens, as they do in figure *e*. This test will do for

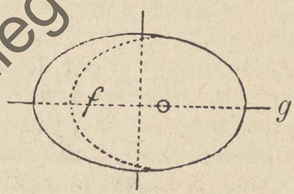
spectacle lenses; but the test for scientific instruments is more elaborate, as we have seen in Chapter IV.




This somewhat circumstantial way of finding the center of a lens can be shortened as suggested by Dr. H. Knapp in this manner: "Look through the lens at two lines crossing each other at right angles; when the prolongations of the lines beyond the lens are unbroken, the point of the lens through which we see the crossing of the lines is the optic center of the lens."

I would advise you now to take at random a dozen spectacles from your stock in trade, and examine them as to the correctness of their optic centers. You will find that many of them, highly valued in the market on account of their trade-mark, are greatly incorrect and good for nothing. It will cease to be a matter of astonishment that some of your customers could not see with one pair of spectacles, and yet found others of the same number pleasant and satisfactory.

To *decenter lenses* is an easy task for any one who understands the nature of the optic center. As we have seen in the previous chapter, under the heading "Prisms," that we have to set them either *base in* or *base out*, it is sometimes necessary, in order to overcome certain defects of vision, also to decenter spherical lenses, and cause



them to act like weak prisms. To fill such an order correctly, it is necessary to first locate the optic center on the lens, then put the zinc-pattern (Chapter VI) as much as possible to one border of the lens, and make a mark around the pattern.

In convex lenses the border nearest the optic center is the base; and any prescription of *base in* or *out* is correctly filled, if we place this part (*f*) towards the nose or temple according to order. In concave lenses the base is at *g*, or just the opposite from that of convex lenses. The base and center of a convex lens always fall together, in concave lenses they are separated; the base is at the border of a lens, and the optic center, of course, in its middle. If, therefore, we have to decenter a concave lens, *base in*, the optic line will appear beyond the middle, nearer the temple, but not towards the nose, as is the case with convex lenses.

In order to explain the object of decentering lenses, I draw your attention to the fact that the eyeball moves in any direction about a common center of rotation by the action of six muscles, four straight ones, the other two oblique. The first are called superior rectus, inferior rectus, external rectus and internal rectus; they move the eyeball either upward, downward, outward or inward, while the two oblique muscles with the assistance of the four recti, rotate the ball in every other direction. Most movements of the eyes are in the horizontal meridian, and are alternately produced by the contraction of the internal and external recti. These two muscles are constantly taxed, and it is no wonder when one or the other will fail to perform its duty satisfactorily. In distant vision the muscles of the eyeball are almost at rest, but close work compels the recti interni to converge in order to direct the visual angle of both eyes to a near point. This is the reason why the internal muscles sometimes weaken and need bracing up, which is done either by prisms, or in very slight degrees of insufficiency by decentered lenses. As soon as a prism with base inward is placed before the eye, the rays will strike it in a more parallel direction, as if they were coming from a distant object, thus allowing the recti interni to relax.

## CHAPTER VI.

### Setting of Spherical Lenses.

We work blindfolded when we are unable to find the center of a lens, and it will be by mere chance, if our work is correct. Rough lenses are not always well centered; if they were, we would have simply to cut the size we need from their middle, and there would be no mistake. Many of them will be found so much decentered as to be useless for sizes 0 and 1, and are fit only for sizes 3 and four, or they may be altogether worthless, except for lenses to be decentered.

We may take notice here of the lenses called the "interchangeable".* They range from No. 3, the ordinary size of spectacles (although smaller numbers are used for children spectacles), to No. 2, the size of eyeglasses, up to No. 1 and 0; even to coquille sizes, No. 00 and 000. Most manufacturers of spectacles adopted these *standard* sizes of lenses, to enable the retailer to exchange the lenses from one frame to another without altering them. A lens of No. 2 spectacles fits exactly the ordinary size of eyeglasses. If you order 1-eye spectacles and eyeglasses, you can exchange the lenses from the spectacles to the eyeglasses, or *vice versa*, as you like, they always fit.

In a well-centered lens the edges are equally thick on their opposite borders, and a little practice will enable

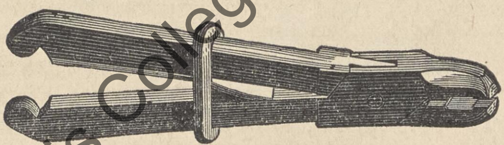
* The first impulse in this direction was given by Noël, who patented a frame without screws, the lenses to be sprung in like watchglasses. Albert Lorsch introduced these spectacle and eyeglass frames since 1869, together with finished lenses of a certain size, about eye 2, which fitted either frame, and which he called "Lenses for the Patent Accommodating Spectacle and Eye Glass." But the term *interchangeable lenses* is of a later date, and came into general use since the Bausch & Lomb Opt. Co. accepted the standard sizes of the American Opt. Co., although other manufacturers still clung to their old sizes, till at present there is hardly any manufactory which will not take, and correctly fill, an order for all interchangeable sizes.

the eye to see at a glance, and without looking through it, whether the lens is decentered or not. This saves us a good deal of time, as the principal test is then quickly determined. But we should not rely altogether on the judgment of our eye in this regard, as it requires a good deal of practice to detect small differences in weak lenses.

Any workman with good tools can perform in a short time more and better work than others who shuffle about the whole day long, wasting time and material, for want of proper implements. The most useful tool in setting glasses is the *model* or *pattern* made of thin zinc. If you have not yet made use of it, prepare a set of the different sizes and shapes of spectacles, as they come into your hands for repairs, and mark them according to the different sizes of the eye. Make a hole exactly in the middle, partly for purposes to be spoken of in the next chapter, and partly to suspend them on the wall within convenient reach, well-assorted according to size and pattern. About three dozen will fully assort you, and will save you, in the course of years, an immense amount of trouble and time.

Another important tool is the *marker*, an instrument like a lead-pencil, mounted at one end with a small diamond. The marker is used to make a scratch around your pattern, after it is placed correctly on the lens. It will not cut the glass as a glazier's diamond, because it is intended only for scratching purposes, and is, therefore, very cheap. On heavy lenses it is best to mark both sides, to prevent the breaking of the lens inside the mark.

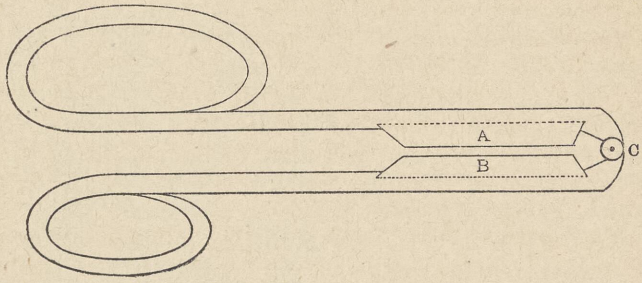
The next tool for our purpose is the *sliding-tongs*, an instrument employed by watchmakers and jewelers, who call it the "dog-nose sliding-tongs;" it is also used by opticians to chip the lenses.



I have found the largest size the best for almost all lenses; but very thin glasses, for instance, for lockets or

watches, which we may occasionally be obliged to grind, can be chipped with common flat pliers. The apprentice should practice this chipping on pieces of window glass, before he attempts to shape a lens and spoil it, perhaps, by inexperience in handling the tool.

The proper tool used in factories, for doing quick and good work in this respect, is represented by the following figure.




I first handled it in 1866. It was shown to me by a workman who called it the "English Shears." As I never found them for sale, I returned to the use of the "dog-nose sliding-tongs," which answer very well the purposes of a retailing optician. The pieces *a* and *b* are dove-tailed into the shears and can be renewed when used out. They are $\frac{3}{16}''$ broad, with straight, flat surfaces. The rivet at *c* is rather loose, so that there is ample play for the shanks to move freely sideways. They are used in a similar way as the sliding-tongs.

The proper way to handle this tool is the following: The tongs, held by the right hand, should be applied loosely to the lens, and worked as we do a pair of scissors, with the difference that at the same moment we close them, we also give the upper part of the tongs a slight inclination to the outside and downward. The lower nose is kept right on the mark by the middle finger of the left hand which holds the lens. This effectually prevents the lens from cracking inside the mark. The outside movement of the tongs throws the chips and glass-splinters from us, and thus saves the eyes from injury. But a fine glass-dust also rises from the lens, and is very pernicious to the lungs. Hold the lens,

therefore, nearly at arm's length, and blow the dust off before you breathe.

As a rule, we should move the tongs outward; but we may come to a place which will not break readily, even by applying greater force. In this case we can sometimes accomplish our task with ease, and without the risk of spoiling the lens, by moving the tongs upwards, using the lower nose for the breaking, and the upper as a guide. This alternate turning up or down of the tongs should be well practiced by the apprentice. In regard to the forward or backward movement of the tongs, it is immaterial which way we proceed with glass, but as to pebbles it should be always the backward movement. As every crystal has a cleavage-plane in its lateral axes, the forward movement may accidentally cause a splitting in the direction of this plane, which rarely happens with the backward movement of the tool.

It is hardly necessary to mention that the stone has to be turned *from* you when grinding. I have seen only one jeweler (and he, too, styled himself "optician"), who turned the stone *to* him, as he had seen done by a street-grinder. Is it to be wondered that he complained afterwards of not being able to get a smooth edge on his glasses, or that they looked as if rats had given them the finishing touch?

I do not think it out of place to say here a few words in general about the grinding of lenses. Almost all manufactories grind them into a sharp bevel, which is in my opinion an unnecessary trouble, and, besides, shows very little sound judgment. The grooves of most frames are not pointed, but rounded off, whether they are made of soft material or metal; and the lens, to properly fill such a groove, should be also rounded off. This will have the double advantage of being less liable to crack, and less troublesome to finish. Sharp-pointed lenses easily split shell or rubber frames, when the latter contract in cold weather, or they themselves are chipped by metal frames, when they are tightly fitted. To overcome this difficulty, and to establish a practical method of fitting lenses to the frames, I will describe the method which I have adopted. After the lens has been well

shaped and sufficiently reduced by the sliding-tongs, I grind off the sharp edge on one side by passing it quickly over the revolving grinding-stone. A few revolutions will accomplish this, and will give it a small but distinctly visible bevel. Then I do the same with the other side, by turning the lens alternately edgewise, to take away its unevenness. In less than one minute my lens has a finished appearance, and needs now only the final adjustment. The edges of the lens have then a rounded form, and when set in frames do not show any roughness, because the polished surface of the lens touches the border of the mounting, thus relieving me of the trouble to polish the bevel, which, however, cannot be avoided when the lenses are thicker than the frames, or when the grooves are very shallow.

In regard to the present universally adopted habit of polishing the edges of lenses, I must confess that I do not approve of it, for the good reason that the reflected light from such bevelled surfaces is annoying to the eyes, and can be easily removed by giving them only a fine ground finish, which the Germans and French call "matt." Even frameless spectacles could be made in this way and would look equally stylish. But this reform can only be effectually introduced by the unanimous co-operation of the oculists in rejecting in future all glasses with polished edges.

The fitting of *bevelled glasses* into the groove of the frame is quickly done, and they are easily ground and shaped if they are of an oval or round pattern. Octagon glasses require more attention, especially when the frames are old and often repaired. The greatest care has to be taken with skeleton and grooved glasses, as the edge must be flat, and the bevel very small. The stone should be used till the lens is rightly shaped and the edge roughly flattened; we should then finish the lens on emery paper Nos. 3 and 2, and lastly on No. 1 and 0 for polishing purposes. If the lens has to be grooved, No. 3 is used only for the edge, but Nos. 2 and 1 for the bevel. It is better to finish the bevel before filing the groove, as a polished surface is less liable to chip in case the file should touch the edges. The grooving is always done

with a round file, never with a four or three-cornered one. The file will soon be smooth if used dry; it is therefore necessary to wet it constantly either with water, turpentine, benzine, or *dilute sulphuric acid;* the latter is most effective. But even these will generally ruin the file after the finish of one pair of lenses, thus considerably increasing the cost and labor. The best fluid for the preservation of the file and drill for our purposes is one that contains an access of camphor. Any mechanic knows that a new file should not be used at once for filing hard iron or steel, without passing it first several times over a soft material, as wood, brass or soft iron, to fill up the deeper parts of the file, giving strength to the exposed sharp points of it. Camphor renders the same service to our file used for grooving glasses, without interfering with its cutting qualities, if the fluid evaporates quickly enough to allow the camphor to clog up the deeper parts of the file. To do this by passing it over lead, would cause it to slip without cutting the glass. The formula for this fluid is:

Spirits of Turpentine............1 ounce.
Camphor Gum...................1½ "
Sulphuric Ether.................3 drachms.

The ether facilitates the solution of the camphor, but volatilizes so quickly that the file would be dry after a few strokes, if the turpentine did not retard its volatilization for a while. Keep the file, therefore, constantly wet while using it, and it will do service for a good length of time.*

The *drilling* or boring of glasses for skeleton or frameless spectacles is done by a drilling machine; but if you have none, it can be done with a round file and the above fluid. Select a file almost of the size of the hole you need; break off the point, and commence the hole by moving to and fro the sharp edge of the file, previously dipped into the camphor preparation. Make a mark on the glass, then raise the file by degrees perpendicularly to the lens, and use it as a drill by turning it slowly between the fingers. Each turn of the drill

* Another excellent fluid for this purpose was lately introduced, called "Diamond Oil," for drilling and filing in glass, porcelain, enamel, etc.

must make the noise of a gnawing rat, otherwise the drill does not bite. When the hole is half through, commence on the other side, and reduce pressure gradually, to prevent a sudden advance of the file when nearly through. The holes are finished off by a three-cornered sinker, much larger than the hole itself, which bevels the edges of it, and prevents the breaking of the lens by the subsequent insertion of the screw.*

There are many devices recommended to shape drills for glass-boring purposes; all agree that they should never be pointed in the middle, but be rounded up, or be flat like a chisel. My favorite drills were always made of a round file (rat-tail), by grinding off two opposite sides, so that it had almost the shape of a square. Holding the file at an angle of 60°, I smoothed the lower surface with the oil-stone, forming a slanting plane, and producing a sharp strong edge to cut with. Another good drill is made of a three-cornered file, sharpened in the usual way, but with one corner taken off, so that the cross section of the drill near the point is that of a truncated cone, and the end of the drill of a narrow chisel-shape.

Not all files make good drills. Either they are not well tempered, or the grain of their steel lacks that peculiar cutting quality which we find in others. If you see, therefore, that your drill does not cut readily, throw it aside and try another file, till you find one that works well. I have often rehardened them, but generally without success; the steel was not precisely of that quality which is necessary to make a good drill. When you have secured such a file, take jealous care of it; I have used some for years, and found them always reliable like old trustworthy friends.

* It is safer to stop drilling as soon as we reach an opening, no matter how small, because it is easy now to widen the hole with an ordinary broach, wetted with the above fluid, in the same way we enlarge a hole in a brass plate, provided the broach is not pressed or forced into the hole, but moves loosely in it.

## CHAPTER VII.

### Measuring and Setting of Compound Lenses.

Simple defects in the refraction of eyes can be corrected by spherical cx or cc glasses; and when their right number or strength is selected for each eye separately, and afterwards correctly set in suitable frames, such spectacles will always give satisfaction. Nine-tenths of those in need of glasses are well suited with simple spherical lenses, and can be rightly served by the optician as well as by the oculist, who, if he is nevertheless consulted by over-anxious people, can do no more than we do: he uses his test-types to find the extent of the error of refraction, and selects the spectacles accordingly. But others require something more than an optician is able to do; these should be sent to an oculist, who, after a professional examination, will give his orders, generally, for compound lenses.

*Compound lenses* are combinations of spherical, prismatical and cylindrical glasses, of which two, or in some cases all three, are ground on one and the same lens. The most simple combination is when the plane sides of a prism are ground into the spherical shape of either cx or cc, without altering the action of the prism.

An order for such a lens will read for instance: + 3 S $\bigcirc$ prism 2°, or perhaps:— 2 S $\bigcirc$ prism 3°.

The combinations of compound glasses are so manifold that they have to be ground always to order, as no optician can have them in stock. We should never rely on the faithful execution of our orders by the grinder; for instance, we may have copied them indistinctly, etc. It is therefore advisable to remeasure all lenses before

we fit them to a frame. Let us take the first lens as a test. We have here a spherical + lens combined with prism of 2°. I suppose that each of my readers has a *trial-box* with all the different lenses; if he has not, he should procure one as soon as possible, for no optician can do without it.* We first take from our box a prism of 2° and place the thick end upon the thin one of our lens. We will see at once that the optic line, which was before near the border, is now in the center. We then take — 3 S and place it on the other side of the lens; these three together must now be a *plane*, or the lens is not correct.

The next combination is the *sphere* with a *cylinder*. One side of the lens is ground spherically, the other side, cylindrically. Such an order reads: + 2.5 S ⌢⌣ + 1.25 C. The test is the same as before. With — 1.25 C we neutralize the cylindrical action in this lens by laying the two axes so as to cover one another perfectly, and by adding — 2.5 S we must again have a plane lens. The grinder always marks the axes by little scratches upon the edges of the lenses, so that we have no trouble in measuring them.

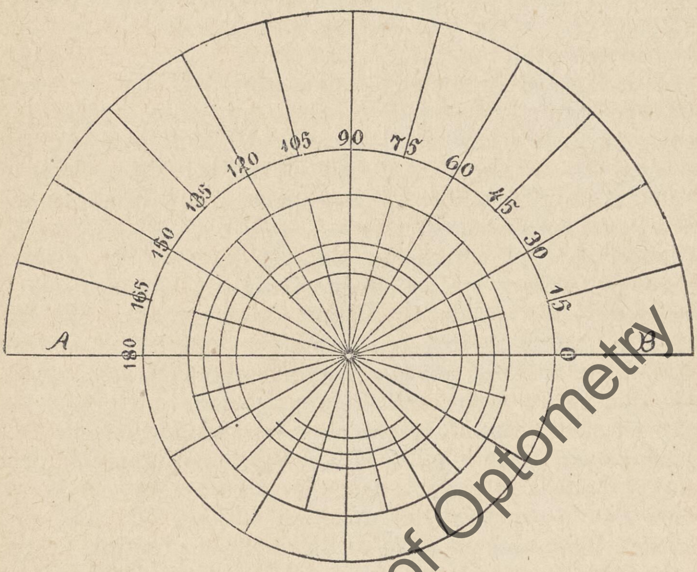
But how, when the grinder forgets to mark the lens, or when we are compelled to find the formula of compound spectacles, having no mark, handed us by a stranger to duplicate them?

Let us first see if they are decentered; if so, we will find one side of the lens thicker than the other, or that a horizontal line is elevated or lowered by turning the lens between the fingers to the right or left. When this is the case, they are combined with a prism. We neutralize this prismatic action by trying different degrees of prisms till we get the optical line in the middle, or till there is no more breaking of the horizontal line. By turning the lens now, the optic line will not move up or down, as it did before the prismatic action was neutralized.

Keeping these two lenses in position, we notice whether

* They were formerly imported from Europe, and Natchet's Trial Boxes were considered the best; but at present, we manufacture them equally as good and cheaper in America.

the cyl. part of the lens is cx or cc, by moving it to the right or left in front of a vertical line. When this line follows our motion, the lens is concave, and has to be defined by a cx cyl. lens. The remainder of our lens is simply spherical, and easily measured. To prove the measurement, and especially to determine the right position of the angle of the cyl. part, we first neutralize the prism, and then the sphere, and lastly find the axis of the cyl. part by following the rule given in Chapter IV. We now mark this line with pen and ink, and place our lens on the following figure.




The center of the lens must be exactly over the center of the circle, and the horizontal line marked on the lens from nose to temple must cover the horizontal line A B. We now observe in what direction the ink-mark points, and we have the degree of the cyl. axis. In making this proof we must hold always the outside of the lens upwards, not towards the paper.

All measurements of the physician refer to the position he takes toward the patient, his right is the patient's left.

I have made for my own use this delineation on strong paste-board, covered with white paper, and find it very handy and more accurate than anything I used before. The little lines are useful guides for finding the right position of the zinc-pattern, and dispense with the labor of searching for the true center through its hole.

I have tried to explain this matter in as few words as possible, and in the most practical way; but some may think it too complicated a task, and lose confidence in their ability to overcome certain difficulties. Just try it, and if it takes a whole hour to measure a compound lens over and over again, you will laugh at this "Sphinx" afterwards, when you will be able to solve the problem in five minutes.

It is absolutely necessary to know well how to measure compound lenses before we are able to set them correctly. I admit that there are difficulties which will puzzle the inexpert, and will lure him into a different calculation altogether. I give here a few illustrations: We have, for instance, a lens — 0.50 S $\bigcirc$ — 1 C ax 90°, the formula of which we do not know. By looking through the lens we see at once that the concavity is in excess of the convexity, if there is any at all. We first look at a vertical line, and notice whether it will follow; if it does, and we pursue our investigation and correct the cyl. action by a suitable cx cyl. lens, we are on the right track. But if, perchance, we had turned the lens $\frac{1}{4}$ of its circumference, and had examined it in this position, which is at right angles to the true cyl. axis, we find that the vertical line does not follow, but acts as a cx cyl. lens, and we have to make the correction in this case with a concavo-cyl. lens. The consequence will be that we make cross-cylinders, and adding — 1 S to the — 0.50 S, which is the real amount of its spherical concavity, the formula found will be — 1.50 S $\bigcirc$ + 1 C ax 180°, which is the periscopic equivalent of the first biconcave lens.

For another test let us take — 0.50 S $\bigcirc$ + 2 C ax 180°. The cyl. axis is easily detected in such a lens by its shape; but, for argument's sake, I suppose we have fallen into the same error, and again produced cross-

cylinders, thus turning + 2 C into + 2 S. Then we have to add + 2 S to — 0.50 S, which would give + 1.50 S, and our formula would be + 1.50 S $\bigcirc$ — 2 C ax 90°, the equivalent of the test-lens.

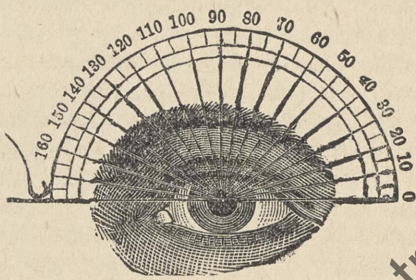
We take another lens: + 1.75 S $\bigcirc$ + 0.50 C ax 90°, and by the same process we will get + 2.25 S $\bigcirc$ — 0.50 C ax 180°. In order to find the formula, the axis should always be marked by small scratches at the border of the lens, or by pen and ink on a lens already fitted.

*The fitting of a compound lens* to a frame next lays claim to all our attention, if we will do justice to the general rule, *i. e.*, to bring the spherical center before the pupil of the eye. When we have marked the cyl. axis in ink across the whole lens, and have neutralized the cyl. action by its opposite, we must next observe where the optic line crosses the lens 90° from the cyl. axis and mark it likewise in ink, but in a manner different from the line of the cyl. axis, say by little dots. We now lay that point of our lens where the two lines cross, exactly over the center of the test-figure, turn the axis of the cyl. to the prescribed angle, and mark by little scratches at the edges of our lens where it touches the horizontal line A B. These marks are guides to direct us in regard to the nose-piece and temple. We must take care that the hollow side of the lens lies upon the paper, because that side will be towards the eye. Our zinc-pattern, after which we mark the lens, must have a hole exactly in the middle, and a marked line from the nose-piece to the temple.

Through the hole we can see the point where our ink-marks cross; we put the line of the pattern so that its continuation strikes the scratches made before as a guide for the nose and temple, and after ascertaining once more by careful examination that everything is right, we run our marker around the pattern. Before chipping off

the superfluous part of the lens, we take a small wooden ruler, place it on the lens, touching the two marks for nose and temple, and make two other fine scratches inside the mark just made for the size of the lens, long enough not to be ground away in the finishing process. After the chipping, we have only to pay attention that our lens retains a nice oval shape, and that the edges are well bevelled.

Any optician who follows these instructions cannot fail to give full satisfaction to the most exacting oculists, no matter at what angle the axis of the lens has to be placed. I believe that some opticians are careless in marking the true center of the lens, and, to find the angle, use designs similar to the following:




I republish this cut as a sample of the incorrect manner in which they are generally made, and to guard against their use by any optician.

In the "'Jewelers' Circular and Horological Review" of November, 1885, I find on page 312, the strange complaint of a well-known oculist, saying: "You will seldom find a workman who can exactly set a cylindrical lens at the axis required, unless the axis named be 180° or 90°. You will probably have to tilt the frame a little, either up or down, to obtain the exact position required. That they set more lenses wrong than right, has been my experience."

If his opticians use the above design to find the angle, their lenses must, of course, be incorrectly set, except in those two directions, as they are the only correct ones. It is, therefore, no wonder that the "Doctor" finds fault with his optician.

## CHAPTER VIII.

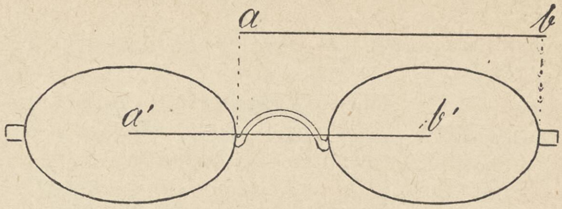
### SELECTION OF SPECTACLES.

This chapter is written for young opticians and such persons as have not yet acquired sufficient experience in the selection of spectacles, to overcome the many vexations incident to their particular trade.

I refer first to the *pupil distance*, as this is the main point of a good fit of spectacles. Pupil distance is the length between the two pupils, measured from the middle of one to the middle of the other. This distance is never smaller than two, nor larger than three inches. The eyes of little children, as well as those of the largest men, are within this compass. The average pupil distance of a grown person is $2\frac{3}{8}$ or $2\frac{1}{2}$ inches, and these are the standard sizes the manufactories use for most spectacles they make. But an optician is obliged to have for any emergency an assortment of all the different widths ranging from 2 to 3 inches. Children require 2″ and $2\frac{1}{8}$″; boys and young girls $2\frac{1}{4}$″ and $2\frac{3}{8}$″; grown persons with small faces use mostly $2\frac{3}{8}$″. A full face needs $2\frac{1}{2}$″ and $2\frac{5}{8}$″. Near-sighted people have generally a large pupil distance, and very often require as high as $2\frac{3}{4}$ inches. I have had in my extensive practice only three customers whose pupil distance reached fully 3″, and all of them were near-sighted. I myself use $2\frac{7}{8}$″, and share the same fate; I, too, am near-sighted.

An ordinary dealer has a fair assortment with spectacles or frames from $2\frac{1}{4}$″ to $2\frac{5}{8}$″, most of them of $2\frac{3}{8}$″ and $2\frac{1}{2}$″ pupil distances.

A simple way of finding the size of spectacles is to measure the *length of the nose-piece and one eye*, which gives exactly the true pupil distance:



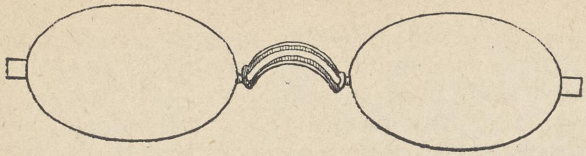

because if you shift the line $a\ b$ to the left, so that $a$ is vertical to $a'$, then $b$ will be vertical to $b'$, which are the true centers of the frame.

Another important point is the selection of a proper *nose-piece*. People with a low or shallow bridge should not, or rather cannot wear eyeglasses; and even spectacles of the ordinary size are not satisfactory, if the nose-piece is not shaped so as to correct the deformity of the nose. Formerly there were only three nose-pieces in use, the C, K and X, to which lately have been added the *snake* and *saddle* nose-pieces.

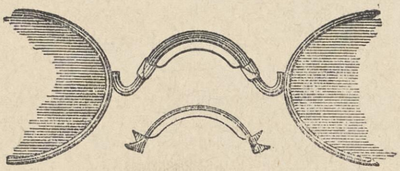
*C* *K* *X*

*Snake.* *Saddle.*

The X and snake nose-pieces are the best for low noses and street glasses; the last is especially useful in removing the glasses far enough from the eyes to save the eyelashes from coming in contact with them. The only objection to most of these nose-pieces is that they are rather thin, and consequently cut the nose, if the skin is tender, as is the case with children and ladies. Instead of making the nose-piece broader, Dr. Hubbel invented a nose-guard, a broad attachment to the nose-piece, which, of course, prevents the cutting of the nose, but at the expense of its look.



A decided improvement in this respect was introduced by the Eggleston & Sibley's "adjustable cork-noses for spectacles." They can be easily applied, look well, protect the nasal crest, and enable us to correct the position of spectacles.



If the nose-pieces were made sufficiently broad, well-shaped and polished, they would not need any lining of turtle-shell or cork, such as have been formerly made at some additional expense, while the broader nose-pieces, answering the same purpose, can be manufactured at almost the same cost as the thin ones now in use.*

*Reading spectacles* should always be in such a position as to permit us to see through the middle of the glasses, without being obliged to bend our head down or forward. We should be able to see at an angle of 45° through the middle of the glasses with our head straight, and by merely lowering our eyes in that direction. These glasses must be placed considerably lower than the street glasses, which, on the contrary, enable us to see through the middle of the lens when looking straight ahead. The military rule for this position is that the eyes should strike the ground at forty steps from us, which is about one hundred feet. Near-sighted persons should be fitted in this way. It looks very bad when the street glasses sit too low, and oblige the wearer, in order to see through the glasses, to throw his head back, as if he were star-gazing.

* Since the publication of the first edition, some manufacturers of spectacles have introduced the *swelled nose*, by widening unduly the middle part of the bridge at the expense of the connecting shanks with the eye wire. Never have I seen so many broken nose-pieces as lately.

In regard to this stooping position for working purposes, I may mention here the reason why people should not bend their head forward, but keep it erect while reading, etc. Any medical book will inform you that the *arteries* which carry the blood from the heart to the head and to other parts of the body, are situated far beneath the surface, and that those blood-vessels which you can see just below the skin are *veins* which conduct the blood back to the heart. Now feel the muscles of your neck when erect, and again when stooping; they are soft and pliable in the first position, and hard and stiff when you bend your head forward. The arteries being situated below the muscles, their action is not influenced by the changes of the latter from the relaxed to the contracted condition; but the circulation in the veins is considerably interrupted by their being compressed to a much smaller size than before. What is the consequence ? The pumping of the blood into the head goes on uninterruptedly; but the flowing off to the heart is obstructed, and we sooner or later suffer from headache, get dizzy, and have to stop work. How many times is a spectacle-dealer puzzled by such complaints of his customers, not knowing how to correct it ? At last these people by chance find among the cheap, common spectacles a *better fitting frame*, and, of course, temporary relief. We not only lose this ill-pleased customer, but drive him to the conviction that twenty-five cent spectacles are just as good or better than two-dollar ones. We are the cause of his at length ruining his eyes by the use of these common spectacles, through our ignorance of the nature of his reasonable complaints. Direct, therefore, great attention to the correct fitting of frames.

The temples of the spectacles should, as a rule, rest on the ears. If one ear of a customer is a little higher than the other, which is not so uncommon as people think, we have to bend or tilt the temple for the higher ear up, and the other one down, else the pupil will not be opposite the center of the lens. In some special cases we may be compelled to incline both temples in order to bring the glasses into such a position that the lower part of them is almost touching the cheeks, and the wearer is

able to hold his work near the body. This may be accomplished also by directing customers to place the temples one or two inches above the ears.

It is absolutely necessary to examine both eyes separately, and to correct each error of refraction by the proper lens. But there are cases beyond the sphere of opticians, *i. e.*, when it is impossible to make the right diagnosis without preparing the eye for such an examination. These patients should be turned over to an oculist; it would be an act of "charlatanry" on our part to pretend to do full justice to such cases. Confine your skill to the limits of your trade, and you will be convinced that it requires all your knowledge, intelligence and energy to fill the place of an expert optician. Over-ambitious young men may commit the error of trying to combine the two branches of an oculist and an optician as far as spectacles are concerned; but is it not the mistake of a builder who would be his own architect, the apothecary his own doctor? The public in general fares better if these branches are divided, and ably represented by competent specialists: on one side the scientific oculist, on the other side the skillful optician, both experts in their particular branches. If we play oculist, why should not the oculist play optician, and keep a stock of spectacles on hand? Therefore my advice: "*Suum cuique.*"

## CHAPTER IX.

### Double Focus Single and Split Glasses.

The failing of our eyesight manifests itself by the gradual lengthening of the focal distance. At first we see well at 14″, then we are compelled to hold our book or paper at 15″; afterwards at 16″, etc.; and the progress of the lengthening of our focal distance, slow at first, soon takes a wonderfully rapid stride, if we hesitate to substitute by spectacles that part of our power of vision which is irrevocably lost. We are reminded here of the common adage: "One stitch in time saves nine"; *i. e.*, the early use of spectacles, when their assistance is necessary, saves our eyesight from its otherwise rapid failure. Nine persons out of ten, who come for their first glasses, confess that they have put off the use of them as long as possible, but have to yield at last. They are not aware of the great blunder they made by taxing their diminished power of vision in the same degree as they did when their eyes were enjoying their full strength.

A well known fact of our "losing sight" is the improvement of distant vision; the sight is going away from us, we gain at the distance what we lose near by. Let us see fifteen years later what has become of our customer's eyes and his spectacles. The gradual failing of his eyesight has compelled him to increase the strength of his reading glasses, till he uses now + 2.50 Diopters (or + 16-inch focus) for near vision; but his far point has also removed, and he finds it impossible to distinguish the features of the minister, or the faces of people in the street 50′ away from him. He asks for street glasses. And here arises the question: Is it advisable to combine reading with distance glasses? The most rational way is to take separate glasses for each

purpose. Most people will follow our advice, and change their glasses accordingly. But we have to deal also with nervous, quick-tempered and impatient customers, who grumble at the slowness of steam, and will have everything go by lightning. They imagine that they have no time to change their spectacles; and indeed some people have not. There is the accountant, whose entries in the ledger from the journal force him to look at items about 2 ft. from him. He cannot keep his seat and accomplish his task comfortably, if he has to jump up, and bend his body, and stretch his neck right or left, to check off and make a correct entry. There is the paying-teller, who must have a sharp eye on his money and the party receiving it. There is the engineer watching his engine, and looking every now and then at the steam-gauge; the teacher, the minister, the orator, the clerk, the lawyer, and many other persons, who find it absolutely necessary to be enabled to see well at a glance far off and near by. Can we accommodate these people without injuring their eyes? We can to a certain extent with double focus spectacles, each glass adapted to its special purpose, the upper part for distant, the lower for near vision. These spectacles are called "Franklin glasses," because Benjamin Franklin was the inventor of them.*

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* Through the kindness of Mr. F. W. McAllister, of Baltimore, I came in possession of a photograph of the following letter, written by Thomas Jefferson, to his great-grandfather:

Washington, Nov. 12, 1806.

Sir:—You have heretofore furnished me with spectacles, so reduced in size as to give facility to the looking over their top without moving them. This is a great convenience; but the reduction has not been sufficient to do it compleatly. I therefore send you a drawing No. 1, so much reduced in breadth as to give this convenience compleatly, and yet leave field enough for any purpose. And I will thank you for a pair of spring frames made accurately to the drawing, and a set of glasses as mentioned in the same paper.

Those who are obliged to use spectacles know what a convenience it would be to have different magnifiers in the same frame. Dr. Franklin tried this by semicircular glasses joined horizontally, the upper and lower semicircles of different powers, which he told me answered perfectly. I wish to try it, and therefore send you a drawing No. 2, agreeably to which, exactly, I will ask another pair of spring frames to be made, and a compleat set of semicircular glasses as mentioned in the paper. These will of necessity give up in part the other convenience of looking over them. With these glasses I will pray you to send me a pair of goggles with clear glass, and a little case of three magnifiers of different powers, shutting up

There are two kinds in use: the double focus *single* or pantoscopic lenses, where the upper part is ground off to a weaker focus, and the *split glasses*, where the distant and near lenses are cut through the middle (or optic line), and finished so that the split forms a straight line in the frame from temple to temple. The optic line in these glasses is, therefore, right on the split. The wearer, of course, is obliged to look below or above that very line where the eye is most at ease, and where it feels comfortable, according to facts demonstrated in Chapter V.

The double focus *single* lens has a serious defect. It confuses the wearer in regard to the true position of things. If we look at a straight horizontal line first through one part of the lens, and in the next moment, by moving the lens, through the other part, we observe that the line is considerably displaced. It is elevated or lowered as we

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in a single horn case. They are used chiefly for reading off the fine divisions of astronomical or geometrical instruments, and are commonly to be had in the shops. I presume these articles placed between two pasteboards may come safely by post. The amount shall be remitted you as soon as known. Accept my salutations and best wishes.

TH. JEFFERSON.

MR. JOHN MCALISTER,
Chestnut Street, 48,
Philadelphia.

No. 1.

Eye glass, long diameter $\frac{7}{8}$ I.
short diameter $\frac{3}{8}$ I.
from center to center of eye glasses $2\frac{1}{2}$ I.

A compleat set of glasses from the youngest to the oldest to fit the frame. Silver frames.

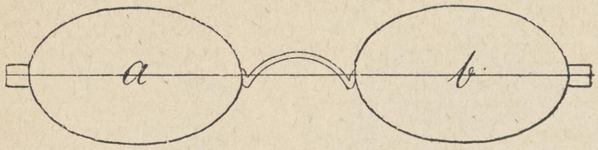
No. 2.

Eye glass, long diameter $\frac{3}{4}$ I.
radius $\frac{3}{8}$ I.
from center to center of eye glass $2\frac{1}{2}$ I.

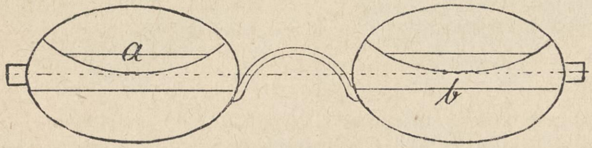
Each eye glass is composed of 2 semicircular lenses, the lower of a greater magnifying power than the upper, that is to say, of the next No. to the upper one.

A compleat set of half glasses to be sent, from the magnifier adapted to the first use of spectacles, to that suiting the oldest eyes, all fitting exactly the frames. Silver frames.

look at it alternately through the upper and lower part. Both parts of the lens act as prisms, bases in the middle.




*Split.*




*Single.*

If the dotted line in the *single* lens is the true position of an object, we see it through the upper lens at *a*, and through the lower at *b*, but never where it really is. People who wear such glasses may, by looking, while descending the stairs, through their lower part, reach the bottom sooner than they expected; and if they have not lost their spectacles by the accident, may stare in bewilderment through the upper part at the place whence they came so suddenly.

Double focus spectacles never render the service which two spectacles will confer to the eye; therefore, we should not recommend them to people who have ample time to change their glasses according to necessity. The absence of the optic line in *split glasses*, and especially the prismatic action in *double focus single* lenses, both in opposition to the first requirements of good spectacles, will in the course of time undoubtedly injure the eyesight. Their use should be limited to such persons who absolutely cannot do without them. We may compare their action with that of a water-proof cloak which will protect against the outside rain, but at the same time will retain the perspiration inside. This is combatting one evil by another one.

In selecting such spectacles, we have to find the proper strength for each purpose. I give here the general rule for this combination: "Ascertain at first the strongest

cx glass with which the patient can see best at 20/XX, then add for near vision plus-glasses, until he can read comfortably ordinary type at the normal distance, say 14 inches." You will find that the relation of distant and reading glasses are calculated by the following rule, in the inch measure:

| | | | |
|---|---|---|---|
| Multiply by | 3 | from | + 16 to + 11 |
| " | 2 | " | + 10 to + 6 |
| " | $1\frac{1}{2}$ | " | + 5 down. |

| | | | |
|---|---|---|---|
| When people wear | + 16, | we may try | + 48 or + 60 |
| " " " | + 11, | " | + 30 " + 36 |
| " " " | + 10, | " | + 20 " + 24 |

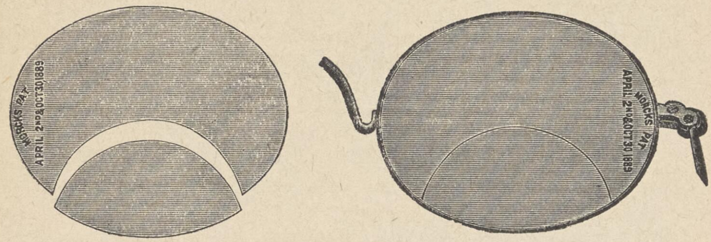
One of these numbers is generally correct. In all cases where people insist on having double focus glasses, we should persuade them to take split glasses.

One of my customers who had at my recommendation commenced with split glasses, was annoyed by the constant remarks that his glasses were broken, ordered them replaced by double focus single lenses. In vain I gave him all the points in regard to their prismatic action, and finally advised him to be very careful, till he had accustomed himself to their use.

About a month afterwards, he entered the store in great excitement, and asked me to replace the split glasses. He had just left the street car, and by stepping over the gutter had missed the opposite curb-stone (which he saw through the lower part of his glasses to be nearer to him than it really was). He would have probably broken a leg, if he had not luckily grasped a lamp-post, just in his reach, to prevent a serious fall.

The prismatic action in double focus lenses can be entirely overcome by taking for distant vision a full lens of the necessary strength, and then cement on it, a little

below the optical line, a small lens which in addition to the power of the distant glass will produce the reading glass. Such lenses were lately introduced by the Geneva Optical Company, as "Morck's Perfection Bifocals."



# CHAPTER X.

## Colored or Tinted Glasses.

"The blind man is a poor man,
And the poor a blind man is.
The one, of course, can see no man;
The other—no man cares to see."

The terms, *blind men and beggars*, are almost synonymous, and indicate the great misery attending the loss of sight. Fortunately we live in an age in which science has investigated the "evils that befall mankind," and we can say with pride: *the blind man shall see;* not by a mysterious wonder, but by the scientific skill of experts.

Among the modern appliances to relieve the sufferings of an afflicted eye, *Protection Spectacles*, set with colored lenses, take a prominent place. They soften the excess of light, otherwise so annoying and hurtful. Since spectacles were invented, people have experimented with different colors, giving preference at one time to this, at another time to that color, according to fashion, entirely disregarding optical laws, till they have settled for the present, with scientific reasons, upon the tint of *smoke*. To comprehend this question thoroughly, we must direct our attention first to the theory of colors in general, and see what we understand by the term "spectrum."

When we speak in an optical sense of colors, we exclude, of course, the pigments used by painters, who include among them even *black* and *white*, which are no colors at all. Black is the absence of light, and consequently of colors; white is the undivided light, containing all colors so combined that the different tints totally disappear. White light is, therefore, called "colorless," although it needs only to pass through a certain medium to be resolved into the brightest colors, as is seen in the rainbow, where the falling drops act as the decomposing agent. The rainbow is a fair specimen of the *Solar*

*Spectrum*, showing the seven spectral colors, *red*, *orange*, *yellow*, *green*, *blue*, *indigo* and *violet*. To these can be added *brown*, outside of the red, and *gray*, outside of the violet. By means of a prism we are enabled to produce this spectrum to perfection, and to investigate the particular properties of each color separately. We thus find that red is least refracted. It forces its way forward like a heavy ball or shot, while violet is the most refracted, yielding readily to the obstruction it encounters in passing through the prism. Scientists have found that the waves of red are nearly twice as long as those of violet, and this accounts for the impetuousness of its ray, which almost overcomes the interference of the prism. The waves of the other colors become gradually shorter, up to violet; and as the smaller waves act more gently upon the tender tissues of the retina, we might guess with some probability that violet would be the softest color to the eye. This would be a gross error. There is a decided difference in the effects of colors on the eye. It is pleasant to look at the dark green of a meadow or the foliage of trees; but it is very trying to use green spectacles, because our eyes are then constantly under the influence of one particular color. In fact, no color is hurtful to the eye as an object to look at; but if a special color is used as the medium to look through, it always acts more or less injuriously in the proportion as the shade is lighter or darker. There is no exception to this rule. We must bear in mind that a healthy eye is able to endure the full force of the whole light, and that any division and exclusion of its essential components will act detrimentally, as would be the case in breathing only oxygen or nitrogen separately, when the mixture of both in a certain proportion is the vital condition of our existence. No separate color is, therefore, a proper substitute for white light, for which our eye is constructed, and so well adapted as long as it is in a healthy condition.

But when the eye is impaired, and cannot stand the full strength of light, should we not shut off some of the most hurtful parts of the spectrum, and allow only the softer colors to act upon the tender organ? Does not

the physician regulate the diet of his patient by depriving him of certain food ? Certainly, so it seems at first to any superficial observer, but even the most rigorous diet does not deprive the patient of any of the necessary elements of his nutriment; only quantity and form are modified. Of the fifteen elementary substances our body contains, the four most essential are oxygen, hydrogen, nitrogen and carbon. To eliminate from the diet of a patient one of these four elements, would not be more irrational than to suppress one color of the spectrum in favor of another. Neither green, blue, nor violet can be substituted for the peculiar union of all colors producing white light. Any shifting of the finely balanced ingredients of white light will act fatiguingly or even perniciously upon the eye. Those of my readers who understand chemical formulæ will readily see the point in question. The (old style) formula of *sugar* is expressed by $C_{12} H_{11} O_{11}$. Now take two atoms, each, of hydrogen and oxygen from the molecule, and we have *vinegar* $C_{12} H_9 O_9$. By a similar process, "sweet" light may be made disagreeable by smothering one or more colors of the spectrum, or rather by increasing the effect of one particular color at the expense of the others.

We have seen that the exclusion of particular colors of the spectrum does not answer our purpose. It remains, therefore, to decide what can be done to protect the suffering eye from the injurious effect of light, without interfering with the essential combination of the thermic, electric and magnetic qualities of the sun's rays, which peculiar combination agrees exactly with the construction of the eye, as the milk of the mother agrees with the healthy development of her infant. The most rational method is to diminish the whole amount of the light by *smoked glasses*. These do not alter the proportion of the different colors, and produce no change in their vibrations. They only lessen the amount of light without disturbing the proportion of its elements. The whole spectrum is thus uniformly reduced, and nothing is changed by smoked glasses but the strength of the excessive light.

To show that no special color by itself will satisfy the eye, I remind the reader here of the well-known experiment of saturating the eye with one color by excluding the others, and observing how eagerly the eye absorbs the complementary color after the test-color is suddenly removed. The easiest way to make this experiment is to cut from colored paper round pieces of the size of a silver dollar. Lay one of these circles upon white paper, and look for half a minute steadily at it, the eyes six inches from the colored circle. By removing this quickly, and looking always at the same place, we will see distinctly the complementary color. This experiment becomes very interesting when we try it with one eye only, the other being shaded. When at the moment of the removal of the test-color the open eye is shaded, we perceive with the other the complementary color as plainly as if that very eye had been directly exposed to the test. If the circle was red, we will see instead a green one, which color is complementary to red. A yellow circle will produce violet; blue produces orange; and green will show red. The eye seeks to be relieved from the strain, and is, therefore much in need of the missing colors. It takes, indeed, a good while before the eye recovers from the fatigue, and is again able to receive the white light without seeing colors.* This experiment was known for many years, but nobody has yet drawn that

* This peculiarity of the eye explains the so-called "Harmony of Colors," which does not depend on the will, or caprice, or personal taste of an individual, but is based on unchangeable laws of nature. By harmony of colors we understand colors placed side by side in such a manner that they do not injure the effect of each other, and be satiating and pleasant to the eye. This is accomplished by adding to one particular color its complementary color in a judicious proportion, so that the eye will rest with ease on such a combination. Those who are familiar with these laws can make such selections in fitting up apartments, in dressing, etc., so that with the greatest simplicity they are able to produce a more favorable effect than is possible with the most extravagant expenditure without this sense of harmony of colors. Ladies are particularly in need of a thorough understanding of these laws, for most of them in the selection of their colored dresses, bonnets and trimmings produce sometimes the greatest discord in the composition of colors. Red and green belong together, so do blue and orange, or violet and greenish-yellow, or indigo and yellow, also white and black. If one of these colors are selected for a dress, the complementary color should be used for the trimmings, and only the right proportion in which they are employed will show the refined taste of the wearer.

lesson from it which it so clearly teaches. * Medical books leave the selection of a special color an open question, and permit the patient to choose for himself, or they are prejudices in favor of one particular color, as the celebrated Dr. Graefe was towards blue glasses, rejecting smoked almost entirely.

It is needless to waste words further in regard to green, blue or violet spectacles, still manufactured and sold extensively to persons who are always on the look-out for something different from what others sell, and which are recommended the higher, the less such "opticians" know of the science of their trade. The great trouble is that the manufacture of colored lenses is not scientific. There are thousands of different shades, due to the careless way in which glass is made. If competent glass-manufacturers would take it in hand to produce a clear colored crown glass, and would publish their formula, after their glass has been approved by leading oculists and opticians, all colored glasses could be limited to *one dozen* different shades, classified with the same certainty as we define now the white lenses by diopters. As colored lenses have only the object of softening the excessive light, it is rational to imitate the common practical way of shutting off the light by closing, according to necessity, the blinds of our windows or turning down our lamps. This is done by smoked lenses in their different shades. There is hardly any exception in all the many defects of diseased eyes where smoke would not do all services expected from colored spectacles. Even healthy eyes are in need of them in countries covered with snow, or where the intense glare of a tropical sun affects them. The Esquimaux make

* Let me relate another curious optical experiment which may serve to show the principle of the stereoscope. If we cut out of black paper two similar figures—two crosses, for example—and place them, their extremities almost touching, at about three inches from the eyes, before a sheet of white paper, we shall see three crosses, the middle one being dark and completely separate. This phenomenon is explained by the simultaneous vision of the two eyes, and it is easy to show this by looking at the objects successively with one eye. The experiment becomes still more interesting when, instead of black figures, we employ complementary colors—red and green for example. In this case we must use a dark background, and there will appear a white cross in the middle.

from wood a kind of coquille spectacles with a slit in the middle, to allow only a limited quantity of light to enter the eyes, and protect them from the dangerous effect of the strongly reflected sunlight which otherwise may cause *snow blindness*.

Smoked lenses are absolutely necessary when the eye is inflamed, after most operations, and in other cases decided upon by oculists.*

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* The study of the nature of colors and their combinations is very interesting, and should not be neglected by the aspiring optical student. How useful such knowledge may prove sometimes is shown by the following anecdote:

"In a large factory one workman, in wielding his hammer, carelessly allowed it to slip from his hand. It flew half way across the room, and struck a fellow workman in the left eye. The man was given in charge of an eminent oculist who after a careful examination stated that the eye was not injured, although the man averred that his eye was blinded by the blow. He brought a suit in the courts for compensation for the loss of half of his eyesight, and refused all offers of compromise. Under the law, the owner of the factory was responsible for an injury resulting from an accident of this kind. The day of the trial arrived, and in open court the oculist, who was summoned by the defense as witness, gave his opinion that the left eye was as good as the right one. Upon the plaintiff's protest of his inability to see with his left eye, the oculist satisfied the court and jury of the falsity of his claim. And how do you suppose he did it? Why, simply by knowing that green looked at through a red glass appears black. He had prepared a black card on which a few words were written with green ink. Then the plaintiff was handed a pair of spectacles with different glasses, the one for the right eye being red and the one for the left eye green. The card was handed to him, and he was ordered to read the writing on it. This he did without hesitation, and the cheat was at once exposed. The sound right eye, fitted with the red glass, was unable to distinguish the green writing on the black surface of the card, while the left eye, which he pretended to be sightless, was the one with which the reading had to be done."

# CHAPTER XI.

## Redressing of Spectacle Frames.

Good spectacles require not only faultless lenses, but also properly fitted frames to render all the services we expect from them. The frames especially should be of the right size, neither too narrow nor too wide, and the nose-pieces be so shaped that, in street glasses, the pupil is exactly opposite the center of the lens. Reading glasses require a lower position in order to enable the wearer, by sinking his eyes for close work, to see also through the middle of the lens without bending his head. Accidents and careless handling will bring sometimes spectacles out of shape, and we are daily requested to redress them. The first attempt I made in this respect was directed only to the temples, which looked to be straight when open, but were pointing in different directions when closed, often so much that I hardly could replace them into the case. I have found very few jewelers who could properly redress spectacles, and I think it, therefore, necessary to devote the following lines for their instruction. The whole manipulation looks to be so simple, but I must say, it took me some years before I found the key for it.

In order to save time and trouble, we should invariably commence with the nose-piece in connection with that eye which is the nearest correct. We should then bend the other eye so that both form a perfect plane, or that they stand in a straight line. Beginners do well to provide themselves with a small ruler about four inches in length, and use it as a test by placing it flatly on one eye, observing whether the other one is in the same plane. Then put it edgewise over the middle of one eye, from temple to nose-piece, and see whether the other glass is not out of line. When the middle part is corrected we examine the temples, and straighten them without pay-

ing any attention to the position they will have in relation to the center part. If one of them extends too far to the outside, we should loosen the screw, or better, take out the glass altogether, and bend the joint upward, thus bringing the temple to a right angle with the center. It remains now only to give the finishing touch to the temples. If one of them stands lower than the other, the lens on that side will be raised to the greatest disturbance of the vision. To correct this, we close both temples, and see which one points exactly to the oposite joint; we take this as the model, by which we correct the other one. We cannot do this by bending the temple itself up or down, for this would undo a former correction, which consisted in straightening the temples "without paying attention to their position." A little reflection soon convinces us that the fault is not with the temple, but with the joint. In order to bend the joint, we must take good hold of it with some blunt cutting pliers nearest the eye, leaving almost the whole length of the joint at our disposal, and by means of strong flat pliers we can bring the joint to its proper position without the risk of breaking it. Any bending of spectacles should be done with two pliers, one in each hand. In addition to the above, we also need round pliers, especially in redressing the nose-piece. To ascertain finally the correctness of our work, we lay them edgewise upon a flat surface, for instance, on the show-case, and see, if the ends of both temples touch the glass; if it does not, we have to go once more over the whole of the aforesaid manipulations. In case one temple has the right position *when shut*, but points side-wise and in a different direction to the other temple *when open*, the fault is then with the joint-pin which is not in the same plane with the lenses. First remove the joint-pin, but not the temple, then insert a broach, and you will find that the planes of the lens and of the broach differ a good deal, showing at the same time in what direction you have to open the hole till broach and lens are level. Before you withdraw the broach, open the temple and you will see that it now points in the right direction, and will keep it after the insertion of a new joint-pin.

# CHAPTER XII.

## Use of Test-Types.

To test vision with different kinds of print, as found in newspapers, etc., was practiced by spectacle-dealers, opticians and oculists up to recent date, and would be the style to-day if not at last the medical profession had taken the matter in hand, and initiated a new era by introducing a rational system. The first noticeable effort was made by Professor E. Jaeger, of Vienna, Austria, in the year 1854, in graduating types from the smallest to the size of posters, in different languages. The advantage of them over the old style was the systematic increase of the size of letters. But no direction was given how to use them, at what distance from the eye each of them had to be read, or what proportion of our eyesight was represented by them. The only advantage over the old, crude manner was that the letters were clear, and the paper white, and that thinking opticians soon acquired by practice, what number of glasses they had to furnish their customers who could read a certain size of print at the usual reading distance. But after all, it was nothing but guess-work, there was no law, no principle, no science in it; they served only to test the eyes at close distance, for reading, sewing, etc., and were of no service to test the eyes for distant vision.

This problem was solved by Dr. H. Snellen, of Utrecht, Holland, in 1868, who determined the acuteness of vision to the visual angle of one minute (1′), instead of forty seconds (40″), as was the general rule up to that time. In Chap. XXIII, "Range of Vision," I based the calculation upon the *old rule*, that objects still could be seen when their visual angle was not smaller than forty seconds; this would enable us to distinguish objects at a distance of 5000 times its diameter (or more

correctly 5156 times). But I think Snellen's suggestion is more correct as regards the application of this rule to practical use. An object of one foot in diameter can, therefore, be seen only at a distance of 3437 feet, instead of 5000′, as stated in that article.

Perhaps some readers do not fully understand the meaning of a visual angle or "angle of vision," and do not know how to find, in common measure, the length of that part of the periphery which represents a given angle. A short explanation will, therefore, not be out of place. We know that each circle, no matter how large or small, is divided into 360°, each degree into 60′, and each minute into 60″ (seconds), or the whole circle into 1,296,000″. Now, if we take a circle of the diameter of one inch, or say one foot, we have to employ the microscope to detect the dimension of the visual angle of one second; but if we take a circle with a radius of the moon's distance from the earth, then each second will represent one mile. We must bear in mind that this mathematical division of a circle in degrees, minutes and seconds is not an exact measure in inches, feet or miles, but only indicates the *proportional* part of any circle, be it small or large. It is very important to remember this, as it facilitates the calculation regarding the sizes of each test-letter for the different distances. Let us take for instance, the letter of C C. It should be seen at 200 Parisian feet from us, which is the radius of a circle, whose diameter is 400 ft. in length, and to find the circumference of the circle we have to multiply 400 by 3.14, which equals 1256 feet. This is the length of the circumference of that imaginary circle drawn around us 200 feet from our eye, as the center of this circle. We have to divide these 1256 feet by 360, to find the length of one degree, which = 3.49 ft. or 41.88 inches, and to find the length of one minute, we divide them again by 60, which = 0.698 inches. This is the width of each of those *twenty-five little squares* we see faintly indicated by dotted lines beneath that test-letter.

Snellen selected the Roman block-letters because every line is of an equal thickness. Some of them are especially adapted for a test; for instance, to distinguish

**O** from **C** or **G**, and **B** from **R** or **E**, or **P** from **F**, we must be able to see plainly the space of one of these little squares, as it is the characteristic distinction of one letter from the other. According to the different distances we occupy before the test-types, these squares alter in size, and limit also the thickness and height of the letters, as each stroke of them is of the width of those squares. Snellen found by numerous experiments that a normal eye just could detect one of them at the given distance, but in order to relieve the eye from all strain, and enable it to see the object distinctly for a length of time, he enlarged the letter in each direction five times, and only indicated beneath it the size of one minute by those dotted lines. The letters themselves represent, therefore, a visual angle of five minutes.

We have seen before, that one minute of the first test-letter was equal to 0.698 inches, therefore, five minutes will be = 3.49″ in Parisian measure. To reduce the Paris inches into American, we multiply them by 39.37 and divide by 37. The following table is calculated this way, and shows the true American measure of every letter at the different distances. Although Snellen confined his test-types to the following distances: 200, 100, 70, 50, 40, 30, 20, 15 ft., etc.; several parties have reproduced them by adding intermediate sizes, which I include in this list to enable opticians, who make use of such types, to measure them and see if they are correct.

| | | | | | | |
|---|---|---|---|---|---|---|
| 200′ | CC | = | 3.49 | Paris or | $3\frac{3}{4}$ | American inches. |
| 160′ | CLX | = | 2.80 | " | 3 | " |
| 120′ | CXX | = | 2.09 | " | $2\frac{1}{4}$ | " |
| 100′ | C | = | 1.74 | " | $1\frac{7}{8}$ | " |
| 80′ | LXXX | = | 1.40 | " | $1\frac{1}{2}$ | " |
| 70′ | LXX | = | 1.22 | " | $1\frac{1}{4}$ | " |
| 60′ | LX | = | 1.04 | " | $1\frac{1}{8}$ | " |
| 50′ | L | = | .87 | " | $\frac{15}{16}$ | " |
| 40′ | XL | = | .70 | " | $\frac{3}{4}$ | " |
| 30′ | XXX | = | .52 | " | $\frac{9}{16}$ | " |
| 20′ | XX | = | .35 | " | $\frac{3}{8}$ | " |
| 15′ | XV | = | .26 | " | $\frac{9}{32}$ | " |
| 10′ | X | = | .17 | " | $\frac{3}{16}$ | " |

The same way we have to reduce the distance into American feet; for instance, 20 Paris feet are 21.3 American. Snellen's suggestion, that the rays from a distance of twenty feet could be considered parallel, can only be admitted from a practical view, and is the utmost limit in this regard. Any shorter distance will tax the accommodation and will not give a satisfactory result.

In using the test-types we should have a room fully twenty feet long from the door or window to the opposite wall, where we should fasten the types about four or five feet from the floor. The room must be, in good weather, well illuminated and the types clearly seen. We place our customer 20 or 21 feet before the types. If he sees No. XX, his visual power (V) is normal and is expressed by the formula V = 20/XX; but if he sees only XXX, then his vision = 20/XXX. The numerator is always the distance, and the denominator is the type he can read. If he only reads CC, then V = 20/CC. Some eyes may be able to see XV, or even X at twenty feet, then their formula is V = 20/XV or 20/X. We cannot make a mistake in the marking of the visual power, when we impress our memory with the general formula, V = d/t; d stands for distance, and t for type.

To attain a more exact formula, we can make use of the signs + and —. If, for instance, a patient can see No. XXX, and one or two letters of XX, his formula can be expressed by 20/XXX +, but if he misses one letter of XXX, seeing perfectly XL, then his formula is V = 20/XXX —. Such formulæ, when carefully recorded, can be utilized two-fold: they serve as reference for future measurements of the eye, and also as a guide for the selection of suitable glasses. As to the latter purpose we only invert the formula, and substitute "diopter" for "type," viz:

20/XXX or $\frac{2}{3} \div \frac{3}{2} = +$ 1.50*s*
20/XL " $\frac{2}{4} \div \frac{4}{2} = +$ 2.*s*
20/L " $\frac{2}{5} \div \frac{5}{2} = +$ 2.50*s*
20/LXX " $\frac{2}{7} \div \frac{7}{2} = +$ 3.50*s*
20/C " $\frac{2}{10} \div \frac{10}{2} = +$ 5.*s*
20/CC " $\frac{2}{20} \div \frac{20}{2} = +$ 10.*s*

The employment of the signs + and — will necessitate the trial of the intermediate numbers of lenses not mentioned here.

Although Snellen's test-types include the finest letters to test the eyes for near vision, they do not answer this purpose as well as Jaeger's, which should be used always in connection with them. Yet, with both test-types an absolute accuracy is not attainable; we must be content with the average statement that a person who still reads No. 1 Jaeger at ten inches from the eye, and No. XX of Snellen's test-types at twenty feet, has normal vision and is not in need of spectacles.

Let me mention here the method which we old opticians formerly made use of in calculating the strength of glasses for presbyopia as well as for myopia. We made the patient read ordinary print, and then measured in inches the distance from the eye to the paper. The optician was standing near the customer with a rule in his hand to measure the length of his reading distance. For those parties who could not read we made use of Lehot's device, consisting of a simple black rule, three feet long, with a white thread strung over its middle from end to end. We placed one end of this rule horizontally upon the chin of our customer, and directed him to slide his finger along the rule to that point where he could see the thread most distinctly. There, apparently, was his focus, and there he saw the thread single, while on this side and beyond the finger it appeared double. This experiment is based upon the same phenomenon as that of the finger and the pencil; if we hold vertically a finger fourteen inches before our eyes, and a pencil at seven inches, then, in looking at the finger, we will see two pencils, but looking at the pencil we see two fingers.

Having thus ascertained the length of his focal distance, we made use of the old rule that all eyes with a longer focus than ten inches, had to use convex glasses, and those with a shorter focus, concave glasses. To find now the proper lens, we multiplied the length of distinct far vision by ten as the standard near-point, and divided the product by the difference of the far and near points. For instance, if somebody could see best at 14″, we

multiplied fourteen by ten, and divided the product by the difference of the two numbers by four:

$$\frac{14 \times 10}{14 - 10} = \frac{140}{4} = + 35 \text{ inches; or}$$

$$\frac{24 \times 10}{24 - 10} = \frac{240}{14} = + 17 \text{ inches.}$$

When the focal distance was shorter than ten inches, say eight or six, we made our calculation in this way:

$$\frac{10 \times 8}{10 - 8} = \frac{80}{2} = - 40 \text{ inches; or}$$

$$\frac{10 \times 6}{10 - 6} = \frac{60}{4} = - 15 \text{ inches.}$$

The strength of those spectacles were generally near enough to commence with as a trial; but as they represented only the average sight of both eyes combined, any regular optician wisely made the necessary allowance for a casual difference in the eyes. — It amuses me now to look back on something I once considered to be strictly scientific, and which is at present thrown aside as unreliable and obsolete.

## CHAPTER XIII.

### Refraction and Dispersion of Light.

The ancients supposed light to be produced and vision excited, by something emitted from the eye. The moderns hold vision to be excited by something that strikes the eye from without. Newton supposed light to consist of small particles shot out with inconceivable rapidity by luminous bodies, and fine enough to pass through the pores of transparent media. Crossing the humors of the eye, and striking the optic nerve, these particles were supposed to excite vision. This was called the *emission theory of light*, and found many strong supporters, among others, Laplace, Malus and Brewster. This theory was first opposed by the astronomer Huyghens, and afterwards by the celebrated mathematician Euler; but it maintained its ground until it was finally overthrown by the labors of Thomas Young and of Augustin Fresnel. These two eminent philosophers separately succeeded in establishing the wave or *undulatory theory of light*, by which all optical phenomena can be explained. They compared light with sound, the main difference being their relative velocity of propagation. The waves of sound require an elastic, dense body, like our atmosphere to make an impression upon the ear, so differing from light, which transmits its waves by a substance of extreme tenuity, called *ether*.

Ether is merely the name of something we know not what, but we know that without its presence, we have to drop the wave-theory. Newton's theory did not require such a vehicle of light because the velocity of his light-missiles were not obstructed by a *vacuum*, but rather accelerated. It was formerly supposed that the space between the stars was perfectly vacant, judging from our own atmosphere, of which the last trace disappears at a

height of about two hundred miles from the earth. The promotion of the wave-theory compelled its supporters at once to fill the universe with some medium to carry the waves of light and continue their motion.

The word *undulation* is from the Latin, *unda*, a wave, and *undula*, a little wave. The selection of this word is not a good one, as it leads the student to confound the vibrations of light with the up and down motion of agitated water, without indicating how one molecule imparts a forward movement to other molecules. I would propose to call it the *vibratory theory*, and would explain its propagation by the presence of heat, as light and heat are inseparable. Light is a high potency of heat, and as heat expands everything, the molecules of ether surrounding and penetrating the source of light ought to be expanded. But as the theory of the nature of ether excludes the presence of pores between its molecules, there is no room for such an expansion; therefore, in its frantic effort to obey an omnipotent law of nature, it only can push the next molecule, or rather a countless line of them, according to the power of the first impulse it receives. Its apparent expansion and alternate contraction without changing its place, is called *vibration*, and is of such a rapid succession that we can form no true conception of it; we have to express the vibrations by billions each second. The extreme tenuity of the ether facilitates the rapid propagation of light, and the continuous impulses, its steady advance (192,000 miles a second).

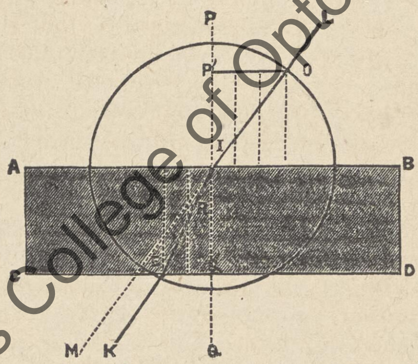
We must beware of the wrong idea, that the atoms of ether are flying about, which is an impossibility, as the whole Universe is equally filled with it. It does not impede the progress of any moving body, but light sets it to an oscillating, and instead of imparting its impulses pell-mell to the surrounding molecules, it always takes the shortest line, the straight one.

When we speak of ether, we imagine it to be the finest matter in existence, whose molecules are indivisible; itself being without motion, allows the world to move in it without the least impediment. And still there must be something finer to fill the space between its atoms, because all molecules are considered to be of a rounded or

spherical shape, leaving yet room for something finer. The subtile argument that there is no limit to the divisibility of matter has little weight, as it would totally destroy matter for the sake of a "theory."

Light is interrupted in its *direction* only by entering a transparent medium of different density from that through which it previously moved. This change of the rays of light from their direct course is called the *refraction* of light. John Tyndall explains this phenomenon by the following illustration: "Suppose light to impinge from air upon a plate of glass, the wave will be *retarded* on passing into a denser medium. If this wave is *oblique* to the surface of the glass, that end of the wave which first reaches the glass will be first retarded, the other portions being held back in succession. This retardation of one end of the wave causes it to swing round, so that when the wave has fully entered the glass its course is oblique to its first direction; it is *refracted*. If the glass into which the wave enters be a plate with parallel surfaces, the portion of the wave which reached the upper surface *first*, and was first retarded, will also reach its under surface first, and escape earliest from the retarding medium. This produces a second swinging round of the wave, by which its original direction is restored. In this simple way the wave-theory accounts for refraction."

The following illustration will explain it more practically.




The figure *a b c d* represents a plate of glass with

parallel surfaces; $l$ is the incident ray which enters the plate at $i$, where we erect the perpendicular $p\ q$. At the height above the slab equal to its thickness, we draw the line $o\ p'$, at right angle to $p\ q$, thus forming the rectangular triangle $o\ i\ p'$. The angle at $i$ is called the *angle of incidence*, and $o\ p'$ is called the *sine* of this angle. After the ray enters the plate, it is bent towards the perpendicular till it reaches $e$, forming another triangle $e\ r\ q'$. The angle at $r$ is the *angle of refraction*, and $e\ q'$ the *sine* of this angle.

We see here plainly that the angle of incidence is larger than the angle of refraction; in glass, for instance, in the proportion of three to two, as seen in the illustration.

The relation of the *angle of refraction* to the *angle of incidence*, though the same for each substance, varies with the nature of different media, each of which has a distinct power. The *ratio* or proportion between them is called the *index of refraction*. For different media, it is as follows:

| | |
|---|---|
| Air | 1.000 |
| Water | 1.336 |
| Oil of Turpentine | 1.475 |
| Crown Glass | 1.538 |
| Rock Crystal | 1.548 |
| Flint Glass | 1.633 |
| Strass or Paste | 2.028 |
| Diamond | 2.439 |

In this table, air is taken as the unit of comparison. The refractive power of crown glass and pebbles is almost the same; flint glass shows a considerable increase, strass even more so. The latter is also a flint glass with a larger proportion of lead, and is known as the *extra white*. The high refractive power in diamonds causes that sparkling clearness called "first water", and is much appreciated by all connoisseurs of precious stones. Spectacle lenses made of diamond would be injurious to the eyes on account of this glaring refractive power.

The refraction of the rays of light passing from one medium to another also causes the separation of light into its different colored rays. This is called the *dispersion* of light. We have seen that refraction refers to the

change in the direction of the rays, while dispersion relates only to colors, produced by an unequal bending of the rays of light. This is best shown by means of a prism. The waves of ether generated by luminous bodies are not all of the same length; some are longer than others. In refracting substances the short waves are *more retarded* than the longer ones; hence, the short waves are more refracted than the long ones. The luminous image formed, when a beam of white light is thus decomposed by a prism, is called a *spectrum*. If the light employed be that of the sun, the image is called the solar spectrum.

The color of light is determined solely by its wavelength; *color*, is to light what *pitch* is to sound. The pitch of a note depends on the number of *aerial* waves which strike the ear in a second; the color of light depends on the number of *ethereal* waves which strike the eye in a second. Thus the sensation of *red* is produced by imparting to the optic nerve a certain number of impulses per second; while the sensation of *violet* is produced by imparting to the nerve almost twice as many impulses in the same time. The waves of the extreme violet are about half the length of those of the extreme red, and they strike the retina with double the rapidity of the red. While, therefore, the *musical scale*, or the range of the ear, is known to embrace nearly eleven octaves, the *optical scale*, or range of the eye, is comprised within a single octave.

The dispersive power varies in different bodies; it is in

| | |
|---|---|
| Rock Crystal | 0.026 |
| Water | 0.035 |
| Crown Glass | 0.037 |
| Oil of Turpentine | 0.042 |
| Flint Glass | 0.049 |
| Diamond | 0.056 |

This table of the *index of dispersion* shows clearly the superiority of *pebbles* for spectacles over any glass, because the eye is most benefited in the length of time by lenses of the lowest power of dispersion. The optical glass of telescopes and microscopes is an exception to this rule; such glass must be of the possible highest refract-

ive power, but its dispersion is neutralized by a certain combination of lenses. The limited use of scientific instruments and their special object, constitute the principal difference between them and the constantly employed spectacles.

If spectacles could be set with achromatic lenses, like objectives of spy glasses, they would be still better than crown glass for the eye, but nobody will carry such a weight on his nose; besides, the high price of such lenses would permit only a limited sale, and therefore, no optician could keep an assortment of them in stock.

The high dispersive power of diamonds causes the fascinating display of beautiful spectral colors, called "first fire," which combined with the "first water" makes this mineral the "King of Gems."

## CHAPTER XIV.

### Achromatic Lenses.

Opticians and dealers in optical instruments are often asked by inquisitive customers to explain the difference between an achromatic and non-achromatic instrument. I, therefore, think it proper to devote a chapter on Achromatism, not only to enable my readers to give satisfactory answers to all questions regarding this subject, but also to make them better judges in selecting their instruments for the stock in trade. — Nobody will expect here a scientific treatise on this subject, as it would involve some of the highest mathematical problems and calculations when applied to scientific and astronomical instruments. I confine myself merely to the primary elements of this interesting study, to keep within the limits of a Hand-Book for workmen.

Achromatism is derived from the Greek word *chroma*, meaning color; therefore, *chromatic*, full of color, and *achromatic*, free from color. Before the invention of achromatic lenses, the astronomers were much annoyed by the colored borders their instruments showed around the objects, which made them appear indistinct and blurred. The stronger the lenses, the more visible was this so-called *chromatic aberration*. Take, for instance, a convex lens of four inch focus and a sheet of white paper; let the direct, or reflected sunlight fall on the lens, and observe the luminous circle on the paper before the lens is in its focus. We see there a distinct blue border in the circle; but when we approach the lens towards the paper, the luminous circle gets gradually smaller till the lens is in its focal point; then the blue color disappears. When we continue to approach the lens towards the paper, the focal point enlarges again, but now the inside border is red. To understand this

phenomenon we must remember that white light consists of seven differently colored rays, having different degrees of refrangibility. The violet and blue rays unite first into a focus, then the green, yellow and at last the red, and only at the middle of these different foci (at green), by the mixture of all the colors, they appear to unite into a common focus apparently without color. Before we reach this principal focus of the lens, the red ray produces the luminous disk, and when we reach the special focus of yellow, the blue ray makes its appearance at the border of the disk, anxious to join the former at the focus of green, which is the only colorless point of the spectrum. But when we reach the shorter focus of the blue ray, which now produces the luminous disk, then the red ray, as the predominant color of the spectrum, makes its appearance on the inside border of the disk. This lack of power on the part of a convex lens to bring the differently colored constituents of light to a common focus, is called the *chromatic aberration* of the lens.

A weaker lens, say of thirty-inch focus, does not demonstrate this phenomenon as well as a stronger one. This is the reason, why telescopes, before the invention of achromatic lenses, were of such an enormous size, sometimes of several hundred feet in length. The chromatic aberration is also seen in cheap opera and spy-glasses with single ocular and objective lenses.

The ingenious Newton by his experiment of interposing a prism in the way of the solar beam, admitted through a small hole into a darkened chamber, made it produce on the wall, not a white circle, as it would have done if allowed to pass on without interruption, but an elongated image, or *spectrum*, as he called it, displaying the rainbow colors. This phenomenon proved the hitherto unsuspected facts, first, that white or common light is, in reality, composed of seven different species of rays; and secondly, that each of these rays is refrangible in a different degree from the other on passing into a new medium, taking a separate course of its own, so that the beam spreads out into the resemblance of a fan. This is called the divergence, or *dispersion* of the rays of light;

and, from some other experiments which he made, he was induced to believe that whatever transparent substances, or media, *refracted* a beam of light in the same degree, or changed in the same degree its general direction, were also equal in their dispersive powers, or made the different rays separate from one another to the same extent. From this followed a very important consequence. The magnifying powers of the common telescope depended entirely upon the refraction of the light in its passage through the several lenses; but it could not undergo this operation without the rays being at the same time dispersed; and this necessarily threw a certain indistinctness over the image which such telescopes presented to the eye. Here, therefore, was apparently a defect in the refracting telescope which admitted of no cure; for the dispersion bearing the same relation in all substances to the refractive power, we can not obtain the requisite refraction without its inseparable companion, the same amount of dispersion. It was this consideration which made Newton give up all thoughts of improving the refracting telescope, and apply himself, as Gregory had done, to the construction of one which should present its image, not by refracting, but by reflecting the light from the object. He, therefore, constructed a mirror-telescope, a "reflector," of the magnifying power of forty diameters, which he afterwards presented to the Royal Society of London. By using a mirror, instead of refracting lenses, he overcame the annoying chromatic aberration to a great extent.

The renowned Euler, on the contrary, propounded (1747) the idea of the possibility to overcome chromatic aberration by a combination of spherical lenses of different density; and the Swedish mathematician, Klingenstierna, demonstrated this idea scientifically, so that ten years later the English optician, John Dollond, manufactured the first achromatic spy-glass.* He made

* Another Englishman, Chester M. Hall, is also credited with having made achromatic lenses as early as 1729, but his invention was not noticed. He was a wealthy man and seems to have been careless of fame; at least, he took no trouble to communicate his invention to the world. But after the patent rights were granted to Dollond, other instrument-makers disputed his original claim to the invention, and it was left to the court for decision. Lord Mansfield, who tried the case, ruled that "it was not the person, who locked his invention in his scrutoire that ought to profit from such invention, but he who brought it forth for the benefit of mankind."

use of Euler's suggestion, that the human eye was achromatic on account of the different densities of the crystalline lens and the vitreous humor. He selected two kinds of glasses which represent similar differences in density, viz.: *flint* and *crown* glass, and ground the denser flint glass into a weak concave lens, and the lighter crown glass into a strong convex lens, which thus combined produce a colorless focus. — When we take the objective lens of an opera glass, and make the same experiment as we made before with the single spherical lens, we will not see the red or blue border at the different distances of the lens from the paper, but will observe only a white disk or circle without color. — The experiment with the single spherical lens also proves that our eye is not perfectly achromatic, as was believed formerly by many scientists, also by Euler. The eye suffers from chromatic aberration as well as from spherical aberration; the latter relates to the imperfect focusing of the rays falling on a spherical lens. The rays nearest to the center of the lens produce the principal focus, which is always longer than the foci of those rays passing through the lens near its periphery. The effects of this spherical aberration is obviated in an instrument by means of a *diaphragm*, which is a blackened shield with a small opening in the middle, permitting only the center-rays to pass, thereby shutting off the peripheral rays, and preventing spherical aberration; but the chromatic aberration in instruments can be obviated only by achromatic lenses.

Our eye has similar contrivances to guard to a certain extent against these imperfections; the iris performs the duty of the diaphragm, and the different densities of the refracting media produce the achromatism. We can greatly diminish the spherical aberration of our eye by looking through a hole in a card made by a pin, but we cannot altogether remove its chromatic aberration. The best experiment to show the comparatively high degree of chromatic aberration in our eye is that with a deep blue glass. If we look at the flame of a candle through such a glass, the flame looks bluish-violet at the length of distinct vision (focus). When we approach towards

the light, the color of the flame remains violet, but has now a red border. When we withdraw beyond distinct vision, the violet flame turns red, surrounded by a blue halo which broadens the more we remove from the light. I believe, my readers will understand this phenomenon without further explanation, as it is analogous to the first experiment we made with a single spherical lens in sunlight.

Now, let us return to the inventor of the achromatic lenses, to John Dollond. We must not imagine that his accomplishment was an easy task, it required many tedious experiments and trials, before he found the proportionate strength of each lens, because the greater dispersive power of flint glass had to be counter-balanced by a less curvature, and the less dispersive power of crown glass by a stronger curvature of the lens; in other words, the index of refraction has to be in proportion to the index of dispersion. The following combination illustrates the above rule: a crown glass of $+2\frac{3}{4}$ inch focus, and a flint glass of — $4\frac{7}{8}$ inch focus will give an achromatic lens of $+ 6\frac{3}{10}$ inches; the crown glass must be always the stronger lens. These relative proportions were later on carefully calculated and tabulated by Herschel, Fraunhofer, Littrow, etc., but Dollond, at his time, had no tables to go by, he had to experiment and try till he succeeded.

His son, Peter Dollond, and the English optician, Ramsden, made great improvements in this direction, especially in the manufacture of achromatic microscopes and astronomical telescopes.

Fraunhofer revolutionized the old methods by the invention of his clearer flint glass in large pieces, which enabled him to shorten considerably the inconvenient length of telescopes, and by using larger objective lenses he produced instruments of great power and perfection. At the suggestion of the astronomer Littrow, another improvement in the construction of telescopes was made by the optician Ploessl at Vienna; he did not join the flint and crown glass together as we find them still in opera glasses, but distanced them in a certain proportion, by which method it was again possible to shorten the tubes

of telescopes. He called his instruments "dialytic telescopes," or simply *Dialytes*.

Among the most noted manufacturers of fine achromatic instruments are Voigtlander at Vienna, Lerebours & Secretan (now Eichens) at Paris, A. Ross (now Dallmeyer), and Beck Bros. at London; also the brothers George and Adolf Repsold, at Hamburg, who mounted the great Russian telescope at Pulkowa, a refractor of thirty-inch aperture, whose objective lens was ground by Alvan Clark & Sons. — The greatest achievement in the line of astronomical telescopes is that at the Lick Observatory in California, a triumph of American workmanship. The names of Clark & Sons, and of Warner & Swasey, who mounted the instrument, will always be remembered as prominent American opticians and mechanics. In fact, the U. S. do not come short in the general race for the superiority in the manufacture of optical instruments. There is David Rittenhouse of Philadelphia; "Chas. A. Spencer of Canastota of N. Y.," famous for the excellence of his microscopic objectives; Henry Fitz of New York, a skillful telescope-maker; W. Wales at Fort Lee, N. J., J. & W. Grunow of N. Y., James W. Queen and Jos. Zentmayer, both of Philadelphia; Bausch & Lomb of Rochester; all of them can be counted master opticians. But the most skillful optician in the world was without doubt the late *R. B. Tolles* of Boston; his achromatic objectives are the finest ever produced, and command the highest prices.

Only since the invention of achromatic lenses we are able to manufacture the various instruments for scientific investigations; but in order to produce a glass suitable for instruments of great accuracy, it was necessary that the glass-industry closely allied itself with the queen of all sciences, "mathematics," by which it was itself elevated from the former lowly position to that of a queenly art. Step by step, we thus can refract or disperse light at our will; we can produce either a blazing fire or a beautiful picture; we can explore the minutest organic or inorganic substance, and solve the mysteries of endless space. By means of glasses we can analyze the constituent parts of the sun and other celestial bodies, and record their ever changing phenomena.

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## CHAPTER XV.

### Anatomy of the Human Eye.

Inventions have occasionally explained the workings of the organs of our body; for instance, the bellows demonstrate the action of the lungs, the pump that of the heart, the *camera obscura* that of the eye, etc. Men used their eyes for many thousand years without the slightest idea of their real mechanism, until the invention of the camera, by an Italian, Battista Porta, about three hundred years ago, gave them a fair explanation of the workings of this organ. Since then it gradually dawned on the minds of scientists, that this implement explained the mechanical workings of our eye better than any theory heretofore promulgated. Porta himself compared his instrument with the eye, but falsely attributed to the crystalline lens the duty which is performed by the retina. About the year 1611, the German astronomer, John Kepler, explained the real relationship of the lens to the retina, and gave a satisfactory explanation of the action of convex and concave glasses. Notwithstanding the most elaborate researches of later scientists and especially of anatomists, to interpret the entire process of the *act of seeing*, they only succeeded to trace the connection of the eye with the cerebrum, and even as far as to the cerebellum, but the mysterious part which the brain has to perform is yet a sealed book for many centuries to come, perhaps forever.—

The two large *sockets* or *orbits* of the eyes as seen in a skull are filled in a living being with muscles, small bloodvessels and cushions of fat, leaving only room for the eyeball and the lids. The direction of the axis of the eyeball does not correspond with that of the orbit; the axes of the eyes are parallel with one another, while those of the orbit diverge considerably in front, and if

prolonged backwards, would intersect at an acute angle a little distance before the middle of the forehead and occiput. Hence, as the optic nerves coincide in their direction with that of the axes of the orbits, each of them enters the globe of the corresponding eye to the inner side of its axis, and, consequently, of the axis of vision. The globe of a normal eye is perfectly round, with the exception of the *cornea*, which forms a slight elevation. When we shut the eye, and press one finger gently on the upper lid, we can plainly feel this elevation by moving the eye. The cornea extents to the outside border of the iris, and is easily seen by looking at the eye of somebody obliquely or in profile, when the iris appears as a straight vertical line, and the cornea as an elevated but transparent section of a smaller ball laid upon a larger one. The *iris*, which presents the colored circle seen through the transparent cornea, resembles a partition placed vertically so as to divide, but very unequally, the interval between the cornea and the lens into two parts. This interval is filled by the *aqueous humor*, which enables the iris to move freely in any direction. The space between it and the cornea is called the anterior chamber, that behind it is the posterior chamber; the first is the largest, and both communicate through the pupil. The iris has different functions to perform; it acts like a diaphragm in a spy-glass, as a screen or curtain, to prevent light from falling on the outer part of the crystalline lens, which otherwise would cause an annoying spherical aberration. It also regulates the quantity of light entering the eye by closing or opening the pupil, which is done by the contraction of its different fibres, either of the circular or radiating ones. When the circular fibres contract, the pupil gets smaller, the contraction of the radiating opens the pupil. The *pupil* is only a round opening in the center of the iris through which the light enters the eye. The action of the iris is not controlled by our will, but is regulated by the sympathetic nerves. The black color of the pupil is partly due to the pigment covering the whole inside of the eyeball, except the retina and lens.* Eyes without this pig-

* See Chapter XVIII, "The Ophthalmoscope."

ment have a red pupil from the reflection of the choroid, as we see in rabbits and some birds, also in albinos. The *retina*, as the optic nerve is called after having entered the eyeball, is spread over the back portion of the eye, receiving the impression of light and conveying it to the brain of which it is merely a projection and is, therefore, in direct communication with it.* Each eye has its separate nerve, but before the two optic nerves enter the brain they apparently cross each other, which explains why one diseased eye very often affects the other; it also accounts for the great sympathy of one eye with the other. The optic nerve of each eye, separately, runs upward towards the base of the skull, and passes through one of the two small openings of this bone into the brain chamber, but they meet here before they are absorbed by the brain. This connecting point is called the "commissure." Some fibres of the nerves do not proceed any further, but are turned to the other eye, *i. e.*, a few fibres from the nerve of the right eye branch off and go to the left eye, and *vice versa*. At the commissure there is still another interchange of the fibres; the larger part of the optic nerve of one eye carries along with it a smaller portion of the fibres of the opposite nerve. After their entrance into the brain, they can be followed up to some extent, but as the fibres are freely dispatched, right and left, to different parts of the brain, the nerves are quickly reduced in size, visible only by a microscope, and the anatomist loses at last all traces of them. *The seat of sight is not yet detected.*

* Starting from the junction of the retina with the vitreous humor, we have:

1. The layer of nerve fibres;
2. the layer of nerve cells;
3. the granular layer;
4. the inner granular layer;
5. the intermediate layer;
6. the outer granular layer;
7. a second fine membrane;
8. the layer of rods and cones;
9. the black pigment of the choroid, which communicates with the sclerotica.

The light, therefore, has to penetrate seven different layers before it sets in motion the rods and cones, which are considered to be the most active parts of the retina. For many years I was in error as to their true location, misguided by incorrect illustrations.

To come to a thorough understanding of the anatomy of the eye, it is necessary to dissect one of a slaughtered animal. The nearest to the human eye is that of a hog or calf, in size as well as in the whole arrangement of its component parts, and which we can readily procure from our butcher. In order to facilitate such a dissection, we ought to have a pair of fine pointed scissors, a sharp knife (a razor is very handy), a pair of pointed and also flat forceps or pincers, and a few common pins, bent into hooks, with a thread attached to be fastened around some nails which we have hammered half their length into the so-called "dissecting board." After having received the eyes, we lay them upon the board and examine first the outside of the eyeball. In case the butcher was well instructed and has left a piece of the *optic nerve* on it, we will see that the eyeball resembles an apple with its stem, which is not exactly opposite the pupil, but is attached a little to one side. We find also the remnants of the *six muscles* which moved the eye, and which had to be cut before extracting the ball from its socket. They are attached to the *sclerotica* about the middle from the pupil to the optic nerve. Next, towards the front part of the eye, we find a loose membrane severed from the inside of the eyelids with which it was connected, called the *conjunctiva*. This membrane is a fine transparent skin covering that part of the eye we see in a living being, and which forms also the inside lining of the eyelids, thus protecting the back part of the eyeball from entering of any fluids or solid objects. We detach this membrane from the ball, which is easily done as it adheres only loosely to it. After the removal of the conjunctiva we direct our attention to the *cornea*, a transparent lamina or scale, the curved covering over the pupil and iris, and the only transparent part of the sclerotica, having the shape of an old fashioned watch glass. With a sharp-pointed knife, or with the razor we can cut a part of it away without touching the iris. One or two drops of water, which filled the space between the cornea and lens, will be spilled, and in examining now the *pupil*, we find it to be only an opening in the iris.

Before we go on in this direction and explore the iris

and crystalline lens, we will turn our attention to the different coatings of the eyeball, and thus enter its interior sideways. The *sclerotica* covers the whole eye, and is with the exception of the cornea opaque. It is a tough, leathery membrane of a bluish or yellowish white color, capable of enduring many injuries without breaking. We will find it a troublesome job to remove a piece of it without injuring the next layer, the *choroid*, which is a rather tender membrane as it consists almost entirely of small blood vessels, covered with the so-called pigment.

Any injury from outside, for instance a heavy blow, may rupture some of its arteries, and give the white sclerotica a reddish or bloodshot appearance. In removing the choroid we tear likewise the *pigment*, which loosely covers the choroid, and yields readily to the scraping of a blunt instrument or the finger nail. It has the appearance of a mixture of potblack and lard. Particles of this pigment sometimes lose their hold upon the choroid, and float in the vitreous humor, causing the annoying sensation of seeing flies (muscæ volitantes) apparently before the eye, which are generally of no importance, as every eye is more or less subject to this occurrence, and in most cases vision is not affected by them. The next part of the eye we come to is the *vitreous humor*, occupying three-fourths of the interior of the ball. It will ooze from the lateral opening we have made, and lie upon the dissecting board as a quivering, perfectly transparent mass, like jelly. We now cut the empty shell into two halves, front and back, and examine the back one. We see here the *retina* expanded in a circular, spherical form, slightly indented where it enters the eye. We should think this spot to be the most sensitive to light, but strange to say, we cannot see there at all, it is the so-called *blind spot* of the retina. The most sensitive portion of the retina is a small space, a little outside of the blind spot, and exactly in the line of direct vision, called the *yellow spot* (macula lutea).

There is now left the upper half of the eyeball for our examination. After having it dipped in water we hold it over some print, when we observe that every letter is magnified. This is due to the *crystalline lens*, a structure

more consistent than the vitreous humor, and is surrounded by a transparent membrane, the *capsule*. The lens extends below the iris; this is a projection of the choroid, closely connected with the *ciliary muscles*, and is also called the ciliary processes. Any contraction or relaxation of these muscles changes the size and position of the lens, causing the so-called "accommodation" of the eye. We understand by this the faculty of the lens of adjusting its focal distance for near and far objects, producing the same effect as when we lengthen or shorten an opera glass by means of the screw. The only difference is that the eye adjusts itself without such an appliance, as the ciliary muscles attend to this changing. We now make a slight cut over the whole length of the lens, carefully severing only the inner side of the capsule, and by a gentle pressure cause the lens to jump out, which will keep its original shape, that of a strong convex lens, but will yield readily to the pressure of our finger. It consists of fine layers of minute tissues and contains comparatively but little fluid. In case of cataract it solidifies, and after its extraction from the eye crumbles between the fingers like dry cheese. We now remove the empty capsule and observe that the *iris* extends a little farther below the sclerotica than it appears from the front. When we direct the iris to strong light, after having washed off the dark pigment which covers the inside and produces its particular color, we are able by means of a microscope to detect the two sets of fibres, the circular and the radiating.

After having cleaned the board, we take the second eye, which was kept in a glass of water, to finish this chapter with some additional remarks not yet explained. We cut from the back part, exactly opposite the pupil, a small piece of the sclerotica (the size of a gold dollar), and also of the choroid, watching carefully that the retina and vitreous humor are left uninjured. If we now encircle the eye by a piece of stiff paper, so that the pupil can be seen at one opening, and the retina at the other, and direct the pupil to a well-lighted object, we see upon the transparent retina the small picture of that object in an inverted position. I will not attempt to ex-

plain here, why we see everything erect and not inverted, as I did not find anywhere a satisfactory explanation of this phenomenon. But after all, it is of little moment to an optician to define something which is not yet fully explained by eminent scientists. I think, all writers on this subject overlook the simple fact that the retina is not the end-point of the act of vision, but that it merely represents an inside lens of the series of lenses in a telescope. It is, therefore, immaterial in what position the object appears on the retina, as the brain really is the last factor in the act of seeing, the veritable ocular lens of our optical apparatus.

After having unrolled the paper we place the eye on the dissecting board, pupil up, and remove the cornea and also the iris with the sharp-pointed scissors. If the cut is made outside of the iris we are able to lift the front center-part out of the ball together with the lens, and we see in the vitreous humor the cavity where the crystalline lens was imbedded. Those of my readers who are of an investigating proclivity and are in possession of a strong magnifier will make the strange observation, that the lens is not perfectly spherical on either side; the front part is elliptic, the back part parabolic, while the inside back of the eye, the retina, is spherical. Those well versed in mathematics will admit that the combination of these curvatures cannot be accidental, and that they must have been designed after a well calculated plan in order to work together harmoniously. — The more we reflect about this wonderful structure, the less proud we are of all our knowledge and learnings. How long did it take the human race to learn that little of this living camera obscura which we know to-day! How many things are yet enveloped in a mysterious darkness! Who, for instance, ever explained correctly the *achromatism* of the eye? Is it produced by the combined refractive and dispersive powers of the lens and the vitreous humor; or is it due to the different densities of the cornea and the lens; or perhaps to the dissimilar curvatures of the lens and the retina? Nobody knows. But notwithstanding of the many unveiled mysteries by which the eye is still surrounded, we must confess that we

know more about the eye than we do of the functions of many other organs of our body; because, what we really know of it is based on mathematical principles relating to light and its refraction, while our knowledge of other organs are to a great extent still theories and conjectures.

## CHAPTER XVI.

### PRESBYOPIA, HYPERMETROPIA AND MYOPIA.

The general belief that the normal eye is perfect, is not true. For instance, the *crystalline lens*, the most essential part of the refracting media, is far from being faultless; it is not optically uniform, neither in shape nor in structure; its anterior surface is elliptically convex, and the posterior surface parabolically convex. Besides, the fibres are arranged around six diverging axes, so that the rays which we see around stars and other distant lights are mere images of this radiated structure. The statements of Alex. von Humboldt and Dr.E.Landolt, that they have known parties who could see the stars as luminous points, only show that these eminent scientists were simply imposed upon. There is also the *retina;* it performs its duty only on a limited spot, the "macula lutea", which we call *direct vision*, applying the term *indirect* to that exercised by the lateral parts of the retina. But all the defects, which result from the inexactness of vision, are compensated for by the rapidity with which we can turn the eye from point to point of the field of vision, and it is this rapidity of movement which really constitutes the chief advantage of the eye over any optical instrument. Helmholtz, while pointing out these and other defects of the eye, resignedly remarks: "I shall be only too glad to keep them as long as I can—defects and all." Indeed, of all the members of the body, the eye has always been held to be the choicest gift of nature. Poets and writers have sung its praises; philosophers have extolled it as a crowning instance of perfection in an organism, and opticians have imitated it as an unsurpassed model. The most enthusiastic admiration of this wonderful organ is only natural when we consider the functions it performs; when we dwell on its pene-

trating power, on the swiftness of succession of its brilliant pictures, and on the riches which it spreads before our sense. It is by the eye alone that we know the countless shining worlds that fill immeasurable space, the distant landscapes of our own earth, with all the varieties of sunlight that reveal them, the wealth of form and color among flowers, birds and insects. Next to loss of life itself that of eyesight is the heaviest. But even more important than the delight in beauty and admiration of majesty in the creation which we owe to the eye, is the security and exactness with which we can judge by sight of the position, distance and size of the objects which surround us. For this knowledge is the necessary foundation for all our actions, from threading a needle to leaping from cliff to cliff, when life itself depends on the right measurement of the distance.—We, therefore, should not find fault with the few *organic* defects of the eye, as there are many others which appear to be partly the result of our artificial way of life, partly of the inevitable changes of old age.

The average good eye is called *emmetropic*, *i. e.* within measure, and all defective eyes are called *ametropic*, out of measure. The meaning of *in* and *out* of measure can be best demonstrated by the following experiments. Take a convex lens of three-inch focus ($+ \frac{1}{3}$) and a white card; mount each on a little stand, and direct the lens to an object twenty feet or more away, so that the rays reaching it are parallel. Then approach the card towards the lens till you have a sharp defined picture; when you now measure the distance between the card and the center of the lens, you will find it to be *three inches*, or exactly in "measure" (Emmetropia).

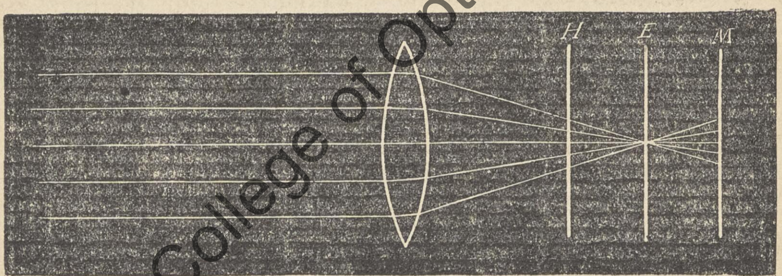
We now place the card at two inches from the lens; instead of an image on the card we have a diffused patch, because the lens is out of focus, and only a two inch lens ($+ \frac{1}{2}$) would restore the picture. But instead of changing the lens we only add to it the difference between $+ \frac{1}{3}$ and $+ \frac{1}{2}$, which is $+ \frac{1}{6}$; therefore, a convex lens of six inch focus held before the test-lens will bring it again into measure (Hypermetropia).

We remove the card now to four inches from the lens,

and we have the same trouble; there is no picture but only a blurred patch, the focus of the lens is too short, and we have to lengthen it by the difference of $\frac{1}{3}$ and $\frac{1}{4}$, which is $\frac{1}{12}$. As we can weaken a convex lens only by the addition of concave lenses, we are obliged to place $-\frac{1}{12}$ in front of the test-lens in order to be again in measure (Myopia).

This simple illustration shows why we have to correct hypermetropia by convex, and myopia by concave lenses. —We also can make use of this experiment to explain Presbyopia and its correction by convex lenses. We put our apparatus again into the same position we had in emmetropia, *i. e.* the card is placed three inches from the lens, and we leave it there without further disturbance, only altering successively the strength of the test-lens. We first exchange $+\frac{1}{3}$ for $+1/3\frac{1}{4}$, and we find by calculation that the difference between them is $+\frac{1}{39}$, which we have to add to $+1/3\frac{1}{4}$, to restore the strength of the original test-lens, in order to obtain a clear picture. Weaker lenses require stronger corrections; so is $+1/3\frac{1}{2}$ corrected by $+\frac{1}{21}$; $+1/3\frac{3}{4}$ by $+\frac{1}{15}$; $+\frac{1}{4}$ by $+\frac{1}{12}$; $+1/4\frac{1}{2}$ by $+\frac{1}{9}$, etc.

If in the foregoing cases we substitute for glass-lens and card, crystalline-lens and retina, we have a fair explanation of the terms Emmetropia, Hypermetropia, Myopia and Presbyopia, respectively.



# *PRESBYOPIA.*

This defect of the human eye can be readily corrected by the use of convex glasses; it is due to the diminishing power of accommodation, and shows itself generally at the age of forty-five years, therefore called "old sight." It is difficult for any one who has fair sight to realize, that seeing necessarily involves some muscular effort, unless it may be when looking at objects too near. Simply to open the lids seems all that is needed, which is practically true of real normal eyes; but we must remember, that sight involves two distinct processes: first, the focusing of the light emitted from the objects looked at, so as to produce a clear picture on the retina; secondly, the perception or appreciation of this picture by the retina. The first is only an optical process, controlled and limited by the laws of optics; but the second is a physiological process of the optic nerve, and depends on its healthy action, which, fortunately, is the usual condition.

The lens of the normal eye is just of the proper bending power to focus parallel pencils of light upon the retina. For nearer objects, there is a muscular arrangement for altering the curvature of the soft, elastic lens, so that it still keeps the focus upon the retina. These muscles give us the power of accommodation, or adjustment for varying distances; and for every minute alteration in distance, we have to make the corresponding, though unconscious adjustment. Every one will find some point within which it is impossible to see clearly; this point is called the "near point," and represents the full and utmost power of his muscles of accommodation. The crystalline lens in children is very elastic and easily acted upon by the ciliary muscles; but it soon begins to increase in firmness or hardness, so that the same muscular effort fails to produce the same amount of change in the refractive power of the lens, and the full action of the muscles fails to bring the near point as close to the eye as it used to do.

Now, when the near point is about two inches from the eye, and the work held at eight or ten inches, there is a large *surplus of reserve power*, and the ordinary use

of the eyes, on near work, is done with ease. But, as years go by, the near point recedes, and the eyes are obliged to call more and more upon their reserve power to accomplish the work they used to do easily. As long as the near point lies well within the working distance, vision can be used almost indefinitely, but when the near point has receded to nine or ten inches, one needs to get almost as near as that to his work, the accommodation is taxed to its utmost, and the strain and fatigue are very great, for no muscle can work at its full power long at a time.

Since the progress of hardening of the lens and recession of the near point goes on very gradually, there is no sudden change, no marked symptom to draw one's attention. It will depend greatly, therefore, on the customary length of time the eyes are kept at work at close range, upon the general health, and supply of nervous force not otherwise called upon, whether and when the eyes begin to suffer from *old sight*. This really begins quite early, but does not reach the condition of needing assistance until the near point has gone off to about ten inches; it simply means overtaxing of the muscles of accommodation,—not on account of the work done, but changes in the effort required to do the work; it means improper wear and tear to the nervous system, just in proportion to the demand for near work. Although the use of glasses can be deferred for quite a long time after they are really needed, the cost is very real and has to be paid in some way. Just as machinery may be run for some time after oil is needed, and accomplish its work well, it is with a waste of power and damage to the parts.

The moment we find that our usual work fatigues the eye, especially at night, it is proper to commence with spectacles, and + 0.25*s* will relieve us from undue strain. But when we do not listen to this first appeal to assist our failing eyesight, we are compelled to remove our work farther away, and only + 0.50*s* will enable us to see again distinctly at the proper distance. A further delay reveals the need of more light, we have to approach the window or door, or draw the lamp nearer to see well;

$+ 0.75s$ is now the correcting lens. — Up to this state of our eyes, we still can see, although with some difficulty, the finest print in the newspaper, and only a few people are aware of having already slighted three calls for correction. Soon they will be surprised that they can no longer distinguish small print, or thread a needle, and if they now come for help we may relieve them with $+ 1s$; but many people will still defer the use of glasses, having been told to do without them as long as possible. They foolishly begin the vain struggle against the inevitable inroads of advancing age, and instead of growing old "gracefully," they resort to imprudent artificial means, to *rejuvenescence;* but as to their failing eyesight, there is no other remedy to resort to than the use of the "dreaded" spectacles. It is utterly useless to "fight age," as far as our eyes are concerned, and the sooner we can convince people, *especially ladies*, of the absolute necessity now to commence with spectacles, the better for them. At this point, the optician can prove that he is something better than a simple mechanic, that he is also the scientific adviser in eye-troubles, which can be controlled by a judicious selection of glasses.

The longer people are opposed to substituting by spectacles that part of their power of vision which is forever lost, the more rapidly their eyesight will fail, and we are sometimes compelled to hand to such inconsiderate persons glasses of $+ 2s$, or even $+ 2.50s$. They are for a while deceived by their splendid distant sight, but become alarmed as soon as they also perceive a failing of this last defense of their folly. They now feel sorry that they were badly advised, and have delayed the use of spectacles till their eyesight is injured beyond redress.

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## *HYPERMETROPIA.**

This defect of vision has its origin in a deformity of the eyeball. In presbyopia, the ball is practically a perfect sphere, but its range of accommodation is impaired;

* This word is derived from the Greek, *hyper*, beyond, *metron*, measure, *opsis*, vision, *i. e.*, vision beyond measure; but some writers call it Hyperopia, omitting the word "metron." This abbreviation is not intended to avoid the significant similarity between the above "long name," and

in hypermetropia (H.), the accommodation is good up to a certain period, but the optical axis is too short, so that parallel rays are not united upon the retina, which by its projected position intercepts them before they are focused, and it, therefore, receives only circles of diffusion instead of a clear image.

Unlike presbyopia, which develops slowly and becomes evident at middle age, this is a permanent defect in the shape of the eyeball; the retina is too close to the lens, and will naturally cause all its pictures to be more or less indistinct. But as all eyes have the muscular power of increasing the strength of the lens, such an eye can, must, and does adjust the lens to the faulty position of the retina, and in that way sees perfectly well, but it has to use up more or less of its muscular power to get what the normal eye sees naturally and at rest. The normal eye is like the rower on smooth water, who utilizes his strength only for progress and rests at will. The hypermetropic eye is like one rowing up-stream, who must spend much of his force in overcoming the ceaseless current, and has only the balance for real progress, and to him rest is impossible. It is, therefore, an overworked eye, not on account of what it does, but on account of its shape; for it has first to overcome its ever-present congenital defect, and in addition all the work of a normal eye as well. This constant, unavoidable strain shows itself sooner or later in some forms of fatigue or exhaustion. There need not be the slightest impairment of vision or pain in the eye, but inability to enjoy continued vision without weariness, headache or inability to fix the attention long at a time; or there may be local symptoms of blurring, smarting, or tired feeling in the eyes. Whether or not the hypermetrope experiences any of these symptoms will depend much on his general health, and the amount of close work done. He may escape them all his life, if strong and well; he may be made miserable in health by them even while in school. Very often, however, since the hypermetrope never is able to

the "long time" it took the medical faculty to explain a defective construction of the eyeball, which surely is as old as the human race; it is simply a verbal translation of the German word "übersichtig" (oversighted), and has the same meaning as Hypermetropia.

compare his eyes with others, as to ease of seeing, he remains in entire ignorance that his sight costs him so much, and he may prove a constant patron of the physician for tonics and assistance to combat his various troubles, or else settle down to the belief that he must endure his discomforts as part of his make-up.

The deformation of the ball is either *acquired*, when in infancy the eye did not receive the proper amount of nutrition during the period of growth, and remained imperfectly developed; or it is *original*, *i. e.* born with the child (congenital), and is often hereditary. The original H. is divided into *manifest* and *latent* H.; the remedy for them is a convex lens.

In testing hypermetropic eyes for spectacles, we must select the strongest convex glass with which the patient can see Type XX at twenty feet. Young persons can use the same glasses also for reading, and should be advised to wear them constantly if the defect is considerable or causes annoyance. Older persons may suffer in addition to their H. from presbyopia, which compels them to use stronger glasses for close work, and weaker ones for distant vision. Old opticians remember with disgust the trouble they had with customers who never could be suited, and who exchanged their spectacles till they were either satisfied, or tired of trying anymore. Surely, their H. was not completely corrected by the spectacles selected for them, and they only found by repeated trials the approximate strength of glasses which gave them temporary relief. The cause of this trouble is, that hypermetropic persons, before using spectacles, tax their accommodation to excess, and when coming at last for glasses, they involuntarily employ a good deal of their accommodation from old habit, and consequently correct with the glasses they chose only a part of their visual defect. That part of H. which they really corrected is called *manifest* H., and that part made up by force of accommodation, and which was not corrected, is termed *latent* H.

We are here confronted by a powerful foe, who baffles our greatest efforts. The old trick of telling people that their eyes will "accustom" themselves to the use

of spectacles we selected, is played out, and we cannot any longer degrade our vocation to the level of a bungling shoemaker, who consoles his trusting victim with the assurance that in a few days the shoe will not pinch anymore. Remember, that the right glass relieves the eye forth-with; but in case we cannot find this glass, we should send the customer to an oculist, who will overcome all latent H. by the application of a mydriatic, which enables him to readily determine the strength of glasses, which will correct the entire or *absolute* H. It is very tempting for opticians to try the same thing, but I seriously warn them not to overstep their limited sphere, and frivolously invoke "a sea of troubles" by the application of drugs, which may, for instance, in Glaucoma, injure the eye to such an extent as to involve them in a costly lawsuit. Even those opticians, who are in possession of a Diploma from an Optical College, are not protected by it from suits for damages in case of an accident.

Hypermetropia has often been confounded with myopia; this generally occurs to persons under twenty years of age. The reason for this mistake is obvious; young hypermetropes hold the book close to the eyes to get the largest retinal image, which again causes the pupils to contract and cut off the circles of diffusion, and also incites the ciliary muscle to make spasmodic efforts to increase the convexity of the lens, so that parallel rays may be focused even in front of the retina, thus simulating myopia. By this exertion the eye will incur frequently the troublesome defect of seeing objects double (*diplopia*). To avoid this annoyance, the child often adopts the habit of inclining the head so that one eye is shaded by the nose, and only the other is employed. The consequence is that the unemployed eye gradually converges, and produces convergent strabismus or *squint*.

A father brings his hypermetropic son to us, stating that he is near-sighted, because he holds the book very close to the eye, and always complains that his eyes hurt him, or are full of tears. Ignorant opticians may agree with such an unprofessional diagnosis, and give him concave spectacles, at the same time instructing the

parent to compel the child to wear them constantly, as the eyes soon would "accommodate themselves" to their use; thus rendering this poor child a lamentable victim of our ignorance. But, not only the parents and incompetent opticians were in error about the real nature of this peculiar deficiency, also the medical faculty was ignorant about it, till Donders, Helmholtz, and many others afterwards, lifted the veil and explained the whole trouble.

Hypermetropia may be easily detected by testing how far off one can read ordinary print through a lens of known focal length; for instance, if one looks through a ten-inch lens and can read clearly at a greater number of inches, say twelve, fourteen, or more, then he surely is far-sighted.

It is by no means necessary for every one who is hypermetropic to wear glasses, for, if he experiences no signs of nervous trouble or over-fatigue, it is perfectly safe to leave the matter alone, although theoretically he needs help. But the recognition of H. should put one on his guard, and would supply a positive diagnosis for many forms of nervous difficulty which might arise, and explain many forms of fatigue and disturbance liable to be laid to the brain, the stomach, the liver, etc. Glasses for the hypermetrope simply take off the constant burden at will, do the extra work for him, and give him as fair a chance as normal eyes have. They save his accommodation for its proper use, and should be worn enough to make his vision comfortable.

The way of dealing with such cases is very simple; the statement of being unable to see distinctly at long distance, is not any longer taken as a proof of myopia, because the next test, to read small print, will show that we have before us a clear case of hypermetropia.

Let me finally draw the attention of the reader to the frequent occurrence of styes on the lids of a hypermetropic eye. Before using spectacles, and also afterwards when latent H. is not fully corrected, the excessive effort of accommodation draws more blood to the eye and to the neighboring parts, than is necessary for their nutrition; the eyelids become swollen and sties are the

final result. Dr. Soelberg Wells (1873) speaks of them as a disease of the connective tissues of the lids, for which he recommends cold compresses, and if they are without effect, hot poultices. He then orders a small incision to be made, and to prevent a recurrence of the disease, to apply a weak ointment of nitrate of silver. But if the patient is feeble and out of health, tonics should be given, and the digestive functions thoroughly regulated. — I believe, Dr. Wells will laugh to-day at his antiquated treatment of this *disease*, and will order suitable *spectacles*, instead of poultices and purgatives.

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## *MYOPIA.*

This deficiency is also described by most writers as a *disease* of the eye, which, in their opinion, gives rise to "posterior staphyloma" (an extensive bulging of the back portion of the globe), or to spasms of the ciliary muscle, etc. Although those symptoms are sometimes accompanied by myopia, yet they are no more caused by it than the softening of the bones by bow-leggedness; there is evidently a confusion of cause and effect. In perusing some of the best authorities on Ophthalmology, I have regretted that none of them are near-sighted, and have treated this subject from their own experience; it would have greatly modified some of their pet-theories about this "disease." We also find in every text-book the traditional error of an undue prominence of the cornea in myopia, although Helmholtz and Donders have distinctly disproved the general truth of this statement by laborious measurements of the cornea and by the ophthalmometer. For the consolation of myopes, I will treat this subject independently of the authorities, guided partly by the experience of my own myopic eye, and partly by the long practice as a dispensing optician.

Myopia is a gift from Pandora's box of civilization, as this defect of sight is not known among uncivilized nations, or in ancient times when people did not use their eyes on small objects, and in artificial light. It is more frequent since the invention of printing, and of improved

lamps and lights. Myopia is always artificially *acquired*, and a tendency to it is then transmitted to the children, although some children of myopic parents do not inherit this debility, but enjoy in youth and manhood perfect emmetropia. Since we are able to correct this deficiency with glasses, the myopes may be well satisfied with their splendid near-sight, and should not grumble at the need of glasses for distant vision, as this inconvenience is fully balanced by their perfect sight at short distance, even to old age.

The names of the former two deficiencies, presbyopia and hypermetropia, indicate exactly the nature of their trouble, but this is not the case with the word *myopia*, which only means "blinking," from the habit of all near-sighted persons to partially close the eyelids, (producing a stenopaic slit), in order to lessen the circles of diffusion and improve distant vision. Still, this word is generally accepted, and does not frighten people half as much as when we tell them they are suffering from brachymetropia, as Donders proposes to call it, or when we mention even the harmless hypermetropia. Our English word *short-sightedness* is far more expressive, and is understood by everybody.

The experiments with the lens and card at the beginning of this chapter illustrates only one kind of myopia, (M), called *axial* M.,because the optic axis is too long, which is always present in pronounced cases of M. But there are many mild cases of this deficiency, where the eyeball is of a normal shape, yet an abnormal convexity of the crystalline lens causes short-sight to a certain degree, termed *refractive* M. Nearly all children are born myopes or hypermetropes; but their M. is only refractive, their lens is so convex, and on account of its great flexibility, so easily rounded and adjusted, that the focal distance of the eye is just in proportion to their diminutive size of body and their short arms. I recollect, that at the age of six years, I could see distinctly at nose's length, although my M. was at the age of fifteen only $-\frac{1}{11}$.

During youth, the refractive M. may become axial, when there is a hereditary pre-disposition to it, combined

with some local causes, as congestion of the ciliary muscles and other tissues, which sometimes leads to softening and elongation of the eyeball. This congestion may be produced by general mal-nutrition of the body with an excessive use of the eyes upon fine objects, by insufficient light or in stooping position. The foundation of axial M. is always laid in childhood. What is said of *progressive* M., is often due to the great difficulty in testing the eye, or to the careless way in which the eyes of myopic children are tested. If one needs — $\frac{1}{6}$, and we hand him — $\frac{1}{10}$, he may be temporarily satisfied with the partial improvement in his former poor distant sight; and when we give him afterwards — $\frac{1}{8}$, he is more pleased, till we reach the full correction — $\frac{1}{6}$. Now, when this loose manner of correcting M. took us three years, we cannot well speak of progressive M., as the progress in this case is only on our side in correcting gradually former mistakes.

But even grown persons may be ill-suited for years without the slightest suspicion that their eyesight could be considerably improved by stronger glasses. I had a lady-customer who asked always for — $\frac{1}{7}$. One night I met her at the theatre with glasses of a different pattern from those she generally bought of me; and as I was well acquainted with her, I was allowed to examine them, and found them to be — $\frac{1}{4}$. When I asked her, why she had never before complained of her insufficient sight, and had always called for weaker glasses than she really needed, she remarked that an oculist had prescribed that number for her, but that she had lately consulted Dr. P. (a peddling oculist), who had furnished her these splendid glasses, (by the way a six-dollar-glass), for only twenty-five dollars. She was well pleased, and could see now "the show" better than ever before. — Similar cases may have led our authorities to exaggerate the optical condition of the myopic eye, especially when they found, after a thorough test, that the old glasses were too weak, although they never before may have suited the case. Hartridge says: "The higher degrees of M. which increase steadily and constantly from an early age, reaching often a high degree, and carrying in their wake

destruction and damage to important ocular tissues, must be looked upon as a 'serious disease'; it is designated by the name *malignant* or *progressive* myopia." My lady-customer could have been counted among the progressive myopes as long as she was wearing too weak glasses; but since they were properly corrected, her M. is no more progressive; on the contrary, she is at present, (after the lapse of twelve years since that episode), well suited with — 1/4½. Nearly all authorities are recommending the weakest concave lenses for myopes, but the strongest convex lenses for hypermetropes; why? I do not find any reasonable answer in all their arguments.* If they are so particular in correcting the absolute hypermetropia, why shall we not correct the absolute myopia, the more so, as the powerful accommodation of a myopic eye indicates an immense amount of latent M., of which no optical writer seems to know anything.

I wish the foregoing not to be construed as if I were opposed to that important and well-established rule, to select the weakest glasses with which a myope can see the test-type XX at twenty feet. On the contrary, I am strongly in favor of even making a kind of compromise between distant and near glasses, as most myopes have the habit of wearing their glasses from morning to night. Hartridge says: "In young people with good accommodation and with a low degree of myopia, the *full correction* may be well borne, the patient wearing such glasses constantly; and it has been observed, that in those, who from youth have worn their full correction *constantly*, for both near and distant objects, the myopia has usually remained stationary." This statement is not far from being correct, but unfortunately, he forgot to mention that the eyelids of most of those myopes are often reddened and swollen from the undue strain of close work with spectacles of full correction. If we cannot induce the patient to buy two pairs of spectacles, one for each purpose, then let us

* "The weakest glass with which V = 20/xx is chosen, because the myope under 45 often "puts on" accommodation on looking at the test-types, and so makes himself seem more nearsighted than he is, and if we are not careful to give the weakest glass, just barely giving 20/xx, we make him into a hypermetrope." — Dr. H. D. Bruns, New Orleans.

adopt the practical method of a sensible parent, when buying clothing for himself and for his growing boy. His body has attained the full growth, is stationary, or even may by degrees shrink and fall off; he represents the myopic eye, and, therefore, should select a rather close fit. But how would a selection on the same principle do for his growing son, who represents the hypermetropic eye ? Would he not out-grow his suit in no time and require a larger one ?

The most sensible writer on this subject is Dr. E. Landolt; he says: "You will find, in nearly all treatises on ophthalmology, myopia described as a serious disease which is liable to bring about choroiditis, alterations at the macula, staphyloma posticum, and even choroidal hemorrhages, and detachment of the retina. Properly speaking, myopia is not a disease, it is only a symptom indicative of a discrepancy between the length of the eye and the focal distance of its dioptric apparatus. It is not the myopia which produces the choroiditis and staphyloma posticum, which in its turn removes the retina beyond the focus of the dioptric system. Thus the defenders of the theory, generally accepted in regard to myopia, will be much embarrassed when they are shown a hypermetrope with a crescent at the edge of the optic disc, a papilla obliquely placed, and even with staphyloma; in a word, with all the conditions at the fundus of the eye which are theoretically characteristic of myopia. In fact, no eye is safe from an attack of choroiditis posterior; the emmetropic and hypermetropic eye can be affected as well as the myopic, because it is not the *state of refraction* that is the cause of it." We see this plainly in cases of 'Second Sight', of which I speak in another chapter.

There is another error, regarding the action of concave glasses on myopic eyes, found in all text-books and accepted in good faith by most oculists and opticians, *i. e.* that concave glasses apparently diminish the size of objects and letters. This is a mistake. We have seen that in refractive M. the eyeball is of the same regular shape as in the emmetropic eye, and that the only difference between them is the greater convexity of the crys-

talline lens in the myopic eye. Now, when we express the visual power of the emmetropic eye by + 1*s*, and that of the myopic eye by + 2*s*, we must admit that all myopes see things at their focus really larger than the emmetropes see them, and when we put — 1*s* before the myopic eye to correct the focal length, we only bring their sight to the standard size, and actually have not diminished the real size of the objects. A myope generally answers, when asked if he sees through the glasses the objects diminished: "No, everything looks larger to me," a common deception with children who confound the present clearness with the former indistinctness, being entirely incapable of judging the real size of things. Of course, an emmetrope will see things smaller through any concave lens, because his crystalline lens has not to waste any surplus of convexity, as we know is the case with all myopes, who on this account do not perceive the least shrinkage in the size of any objects by the use of suitable concave glasses.

There is another peculiarity in the myopic eye which has not yet sufficiently attracted the attention of optical writers; it is the small handwriting of all myopes. Although this habit is contracted by them before they ever used spectacles, we still find this practice to a good extent after we have partly corrected their near-sightedness according to professional rules. In my opinion, M. is the least explored deficiency of all ophthalmic errors, but I hope that scientific men will make it a special study, and soon benefit the world, as Donders did, in regard to H., with a more correct treatise on myopia. We surely have to take in consideration what we may term *latent* M., otherwise we are at a loss to explain the small handwriting of myopes who wear spectacles.* If there is also *absolute* M., let us fully correct it, as we have seen it done in H. The future investigator has to drop at once the erroneous opinion that a myopic eye, bring-

* "Myopes write small because when young the writing held at the focal distance of their eyes looks to them sufficiently large, — the habit formed when learning to write is never abandoned. Besides the use of a *correct* (not too strong) glass does not materially diminish the size of the object. That mainly depends on the distance of the lens from the screen (retina)." — Dr. H. D. Bruns.

ing everything near to the eye, is more strained as to its accommodation than the emmetropic eye is by reading at a distance twice or three times that length. Watch-makers who necessarily use a strong convex lens before one eye, thus making themselves artificially near-sighted, and work at the focal distance of that lens, are not liable to become myopic; proving that close work *without convergence* does not tend to produce myopia. The professional microscopist is another illustration of this fact. As long as a myope is not compelled to hold the book nearer than six inches, the *recti interni* are still able to center both eyes for near work, though we must admit the strain to be considerable; but when the focus of the eye is shorter than six inches, the myope will soon form the habit of using only one eye, and *divergent squint* will be the consequence, if his M. is not corrected for near vision. This is especially the case with myopes under twenty years.

The phenomenon that some persons are presbyopic and myopic in the same eye, needs a short explanation.* The text-books call this state of vision "Myopia in Distans," or short-sight at distance, but they do not explain what changes in the eye have taken place to produce this phenomenon. Donders thinks that it is often due to abnormal dilatation of the pupil, and Von Graefe attributes it to a peculiar spasm of the ciliary muscle during the attempt of relaxation in adjusting the eye for distant objects, but both explanations do not unveil the *cause* of the "dilatation" or of the "spasm," which surely must be due to certain defects in the mechanism of the eye. Before I offer my own theory on this interesting deficiency, let me correct the general error that the normal eye is in a state of *absolute rest* when it is

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* "An eye can only be myopic and presbyopic when the myopia is less than 2 or 2.50 D (*i. e.* the focus longer than 16 or 18 inches), and the patient 40, or *prematurely* old and feeble in accommodative power. I have sought in vain for evidence of "negative accommodation" (*i. e.* power to flatten the lens). I never have seen a myope who could by effort reduce his *true* myopia, or a hypermetrope who could increase his defect. In the case above mentioned, a presbyope who had M = 2 D, would have to use a convex near glass, or hold his reading off the ridiculous distance of half a meter (20 inches). Of course, he would need — 2 D for good distant vision." — Dr. H. D. Bruns.

adjusted to bring parallel rays to a focus upon the retina. The far-point as well as the near one necessitates an effort of the accommodation, and the *point of absolute rest* lies consequently between the two. Accommodation is produced by the action of the ciliary muscle, which, similar to the ciliary processes (the iris), consists of two different sets of fibres, the circular and the radiating. The contraction of the circular fibres adjust the lens for near vision, and the contraction of the radiating for distant vision. Their action is antagonistic; the contraction of one set of fibres relaxes the other, and only when both sets are in a state of absolute rest, *distinct vision ceases*, we are gazing into vacancy, and feel the change of the tension in the eye the moment we try to focus for an object either near or far. There are two ways to explain the above deficiency: either the ciliary muscle has lost some of its power to properly shape or adjust the lens for different distances, though the lens may be still in its normal state; or, if the muscle has retained its full power, the lens may have lost some of its flexibility in getting harder and more rigid, thus offering greater resistance to the action of the muscle; or there may be a combination of both deficiencies. In all cases, neither the contraction nor the relaxation will be completely performed; the muscle cannot reach its former extreme points of accommodation, — its action resembles the shortened vibrations of the hair-spring of a watch whose main-spring is almost run down. For near vision the lens is not enough rounded up to dispense with convex glasses, and for distant vision it is not sufficiently flattened to do without concave glasses.

It is immaterial for opticians to further investigate the question, which of the two deficiencies in the accommodation of the eye is more frequent, the loss of muscular power or the hardening of the lens; although a little reflection may lead us to the conviction that the muscular debility occurs more frequently in earlier life, and that the hardening of the lens is mostly confined to old age, especially when "second sight" fore-shadows greater trouble.

# CHAPTER XVII.

## Astigmatism.

From the beginning of my studies in optics to the present day, the word astigmatism has always impressed me with a devout feeling; and at this very moment, as I write about it, I feel as if I had entered a temple of worship, and were listening to a hymn of praise to the great achievements of the human intellect. History glorifies the victories of brave soldiers; but their deeds spread woe and misery among thousands of their companions, while the victories of scientific investigators create rejoicing and happiness. The researches in astigmatism are, indeed, the crowning cupola of that magnificent structure, "Ophthalmology." Although its beginning dates back a whole century, its completion is the work of the last thirty years. Science generally progresses slowly; the first elements of it appear in the form of isolated facts. As these multiply, a kind of mutual connection appears possible. Possibility becomes successively probability; probability, certainty. And thus the individual truths of science, like the wheels and pinions of the engine, become all subservient to one great common end. In no branch of science has this been better exemplified than in our knowledge of the modifications of the refraction and accommodation of the eye.

The first discoverer of this peculiar defect of the eye was Thomas Young, in 1793. His eyes, when in a state of relaxation, collected to a focus on the retina those rays which diverged vertically from an object at the distance of *ten inches* from the cornea, and the rays which diverged horizontally from an object at *seven inches*. Consequently, the refraction of his globe was stronger in the horizontal than in the vertical meridian. In 1827, Professor Airy published a remarkable instance of the same anomaly in

his left eye. In this, the furthest point of distinct vision for vertical rays was *three and a half inches*, and for horizontal ones, *six inches*; the eyeball thus being nearly twice as myopic in the vertical than in the horizontal meridian. To Airy likewise belongs the merit of first having applied *cylindrical lenses* for the correction of astigmatism. In Young's case, the astigmatism originated in an irregularity of curvature or position of the crystalline lens, therefore, called *lenticular* astigmatism, while Airy's deficiency was due to an imperfection in the curvature of the cornea, called *corneal* astigmatism. When Donders, in 1862, published his work on astigmatism, only eleven cases of this optical defect had been recorded, but he states that astigmatism is a very common disturbing cause of vision, and that many cases hitherto but imperfectly corrigible by spherical lenses, are almost completely so by cylindrical ones, either alone or combined with spherical ones. — To-day we may count the cases which are successfully corrected by cylindrical lenses, by the million.

Before we go into details, it may be proper to remind the reader of some peculiarities, present more or less in every eye. The average eyeball is considered to be a perfect sphere, but this is not mathematically true, — on account of the cornea. What we see of the eyeball, when the lids are open, is not a circle but an ellipse; this is the reason why our field of vision is laterally fully 160°, and vertically only 120°. The large lateral scope of vision may be the cause of the cornea being somewhat flattened in the horizontal meridian, by the constant pressure of the edges of the eyelids, while in the vertical direction this pressure is very slight. If we take an egg, or the bowl of a spoon, and draw a line from point to point, it will represent the horizontal meridian of the eye, and the line across the middle will be the vertical meridian. Of course, each of these meridians has a different length of focus; the vertical is more convex and will concentrate the rays to a shorter focus than the horizontal; and to correct this deficiency we have either to lengthen the focus of the vertical meridian, or shorten that of the horizontal one. Spherical lenses cannot do this, because any shortening or lengthening would be equal in both merid-

ians; only in cylindrical lenses have we the means of performing this feat. According to Chap. IV, the cylindrical lens is a plane in its axis, and only at right angle, or ninety degrees from the axis, does it act as a spherical lens of the same denomination. Prof. Airy, for instance, had to lengthen the focus of his vertical meridian by a concave cylinder, axis 180°, and if we suppose that his right eye had a focal distance of ten inches, he then had to combine the cylinder with the proper spherical concave lens, to equalize the focus of the left and right eye.

A common cause of astigmatism is that the cornea and the crystalline lens are not symmetrically placed with regard to their common axis, they are not accurately centered. This defect is found in most human eyes, but is perhaps corrected, in mild cases, by an irregular contraction of the ciliary muscle, in the same way as we involuntarily adjust the center of gravity of our body by stooping forward when we carry a heavy load on our back.

Astigmatism is sometimes congenital; but in most cases is mechanically produced by injuries, wounds, ulcers, etc., or is due to the pressure of swollen lids upon the cornea or to sties, which are often met with in hypermetropic eyes; wherefore these two deficiencies are frequently combined in the same eye, called *hypermetropic astigmatism.* If a myopic eye is thus affected, we call it *myopic astigmatism.* — A fruitful source of corneal astigmatism was patented in 1867 by Dr. E. B. Foote of N. Y., called the "Eye Sharpener." This physician entirely ignored the organic changes which take place in the eye by age, as we see by the first lines in his circular: "It is pretty generally understood that the reason why people advancing in age are compelled to hold the work or newspaper farther from the eye than they were accustomed to do in youth, is because the eyeball has become flattened." He, therefore, invented a sucking-contrivance in the shape of a cup, "to keep up the fullness of the cornea," and attached to it a depressing-device to flatten the cornea of myopes. Some of my customers were lured into the meshes of this ignoramus to their great sorrow; let me give you an instance. A prominent lawyer in N. O. was near-sighted

to the extent of — $\frac{1}{8}s$ or 5 D*s*; these glasses gave full satisfaction for many years. One day he asked for — $\frac{1}{9}s$, then for — $\frac{1}{10}s$, till he called for — $\frac{1}{12}s$, all in one week; but he soon returned to almost the same number he started from; his apparent improvement was nothing but a grave illusion. For several years after this, I lost sight of him, perhaps he consulted another optician; till lately he handed me an order from an oculist for — 5*s* ⌒ — 2*c* axis 90°, which was the final result of his previous experiments with the Eye Sharpener.

Astigmatism is divided into three varieties:

2. Simple *hypermetropic* and *myopic* astigmatism.
2. Compound " " "
3. Mixed astigmatism.

All these forms are called *regular*, while the existence of different degrees of refraction in one and the same meridian is termed *irregular* astigmatism. It is not necessary for a practitioner to be thoroughly acquainted with the many technical terms used in this respect. Landolt says: "In the vast majority of cases, fortunately, it suffices to know the total astigmatism of the eye, without questioning ourselves as to what part is due to the cornea and what part to the crystalline." —All books treating of astigmatism are written by physicians for physicians; their writing is, therefore, too much interlarded with Latin and Greek, that it is all Greek to the plain optician, who has not had the benefit of a scientific education. But such terms are sometimes very handy in technical explanations, partly for brevity, partly for exactness of expression. The word astigmatism is one of them; *stigma* means a point, and *astigma*, no point, *i. e.*, the rays of light are not uniformly united on the retina to a point or focus. This is also the case with all other ametropic eyes, but they can be easily corrected by spherical glasses, which are of no value to correct astigmatism.

To discover astigmatism, several devices, such as a fan, or a dial, have been introduced; but I found Dr. Pray's striped letters most convenient for indicating one of the chief meridians. They can be used by every one,

whether he can read or not, because it is only necessary for the patient to state which letter is the blackest. Dr. Owen, recently, improved upon Pray's design by publishing a card comprising two sets of letters, each one $2\frac{1}{2}$ inch square, formed of lines which radiate towards every ten degrees, in order to find readily any faulty meridian from 10° to 180°. With the assistance of the improved trial-frames and a complete set of lenses, it is not difficult to correct most cases of simple and compound astigmatism. — The simplest case is when one meridian is still emmetropic; we test such an eye with Snellen's test-types. The patient will state that he sees type XX quite well, but that a continued gaze at them causes a heavy feeling in the eye, which soon will be followed by headache. We then take a convex and a concave lens of 0.50*s*, one in each hand, and place first one, then the other before his eye; if he does not find any improvement with either of them, then a quick glance at Pray's letters will disclose that some of them are blacker than others. We now take the trial-frame with either + or — 1.00*c*, the axis placed at right angle to the blackest stripes he before had pointed out. The lens which improves his sight is taken as a guide in trying if stronger or weaker ones will still give better satisfaction. It is necessary to try both, convex and concave cylinders, as we do not know if we have to shorten or lengthen the faulty meridian. But, where is the faulty meridian? Seemingly in that direction where we see the lines pale or indistinct; yet, this is an error, or an optical delusion, as the faulty meridian is just ninety degrees from it, or in the direction of the blackest lines. To explain this paradox, I have to remind you of the peculiar propagation of light by *waves*. A horizontal ray is propagated by waves which move up and down, vertically, or at right angle to its direction; in the same way is a vertical ray produced by horizontal vibrations. Suppose we take some thin slips of paper and pile them up to a column, then the slips will lay horizontally, but the column will be vertical, and to build a horizontal line we have to place the slips vertically. When we, therefore, look at Pray's letters and find those of the vertical stripes the

blackest, we see them with the horizontal meridian of our eye; and if the horizontal stripes are the blackest, we perceive them with our vertical meridian. The faulty meridian, therefore, lies always in the direction of the blackest line, and we have to put the axis of the cylinder ninety degrees from it.

Sometimes the faulty meridian of one eye is at right angle to that of the other eye, when in binocular vision they will correct each other; it is, therefore, absolutely necessary to test each eye separately. This kind of astigmatism is called *simple hypermetropic or myopic astigmatism*, according to the nature of the correcting cylinder, which will be either plano-convex or plano-concave.

The *second* variety of astigmatism is the combination of astigmatism with hypermetropia or myopia. Its correction depends entirely upon the relative proportion of each deficiency. Prof. Airy, for instance, had to correct his astigmatism before he could equalize the focal distance of his eyes by the addition of concave spherical lenses. But if hypermetropia or myopia is in excess of the astigmatism, we better correct them first in the usual way, and finish off by adding the correcting cylinder. It happens sometimes, after we have evidently corrected the full amount of hypermetropia or myopia, and added the cylinder, with axis at right angle to the direction of the blackest line, that we have to turn the cylinder ninety degrees, in order to get clear vision. This strange incident could be called *apparent astigmatism*, although there is no such thing, because the double nature of spherical lenses, being crossed cylinders as well as segments of spheres, will easily explain it. Let me refer to my own myopic-astigmatic eye, which sees the horizontal lines the blackest; the faulty meridian, therefore, is at 180°, and the lens which is to me most satisfactory and pleasant, is — $2s \bigcirc$ — $1c$ axis 90°. But it would be an excellent illustration for the theory of apparent astigmatism had I corrected my myopia by — $3s$, and then the apparently faulty meridian by + $1c$ axis 180°. When we look at the two combinations:

— $2s \bigcirc$ — $1c$ axis 90°, and
— $3s \bigcirc$ + $1c$ " 180°,

we will find them to be equivalents, only my eye prefers the biconcave to the periscopic form. If, therefore, the axis of the cylinder has to be placed in the direction of the apparently faulty meridian, instead of ninety degrees from it, we have simply over-corrected the hypermetropia or myopia of the eye, and have made an error in the selection of the spherical lens. — The lenses which correct compound hypermetropic and myopic astigmatism are called Compound Lenses.

The *third* variety of astigmatism cannot be well corrected without the application of a mydriatic, and is, therefore, beyond our reach.

The *irregular astigmatism* even eludes the greatest efforts of the expert oculists, because we opticians cannot produce the suitable lens for its correction.

# CHAPTER XVIII.

## The Ophthalmoscope.

Prior to the invention of the ophthalmoscope it was impossible to explore the interior of a living eye. Scientific men tried in vain to interpret this strange fact, for apparently this should have been easily accomplished, since the depth of the eye is shallow and all the structures situated in front of the retina are transparent; yet it proved to be a conundrum, until Helmholtz explained the whole mystery.

The optical law that *the angle of reflection is equal to the angle of incidence* had been known two thousand years. Polished surfaces and the bottom of shining vessels with wide openings were used to demonstrate its correctness; but when the angle of incidence became so small as to be almost, or completely, parallel to the angle of reflection, as is the case when light enters the eye and should be visibly reflected through the pupil, this law was entirely overlooked, and many theories were formulated to explain the black appearance of the pupil. A faint luminosity of the eye, especially in the tapetum of dogs and cats, had been observed from the earliest times, and gave rise to the general believe that the human eye was also luminous under certain conditions. With a kind of popular superstition it was regarded as evidence of a voluntary nervous irritation on the part of the animal, although nothing of the kind could be perceived in the human eye.

The first who opposed this general error was the Arabian, Alhazen, and afterwards the Italian, Battista Porta, but their protest was not noticed; on the contrary, when Méry, 1704, observed the retinal vessels of a cat under water, the old superstition was strongly revived, till in 1810, Gruithuisen and Prevost repeated the very experi-

ment in the dark, and of course did not see anything. They, therefore, denied the self-luminosity of the eye, and referred the aforesaid phenomenon rightly to *reflected light*. This was the end of the old delusion, and it was reserved to our century to solve the question: *why is the pupil black?*

In 1846, Dr. Cumming published a paper "On the Luminous Appearance of the Human Eye," and rarely has an observer approached closer to an important discovery without actually reaching it. The next year, Dr. E. Brücke published the account of an experiment in which he allowed the light from a lamp to enter the observed eye, whilst he approached his own eye very closely to the flame, only protecting it from the glare and heat by a thin screen. Both, Cumming's and Brücke's principle was for the observer to regard the eye in a direction nearly parallel to the entering rays of light. But Helmholtz, in 1851, was the first who clearly perceived the true optical relation between the incident and reflected rays, and then was led to the invention of the eye-mirror, or as he called it, the Ophthalmoscope.

Instead of placing the light in front of the patient's eye, Helmholtz put it at the side of the patient's head, and reflected the rays by a polished plate of glass into the observed eye, while, without great annoyance to himself, he looked through the transparent plate into the illuminated eye of the patient. Thus did it for the first time become possible to observe the details of the interior of the eye — its nerve and vessels. All previous observations on the human eye had been limited to observing simply its luminosity. Notwithstanding, however, the magnitude of Helmholtz's discovery, the difficulty of manipulation, the feeble illuminating power, and the limited field of view of his ophthalmoscope would in all probability have restricted its application to that of a philosophical instrument, had not others taken up his idea and, by introducing great improvements, made it forever the most important implement to every oculist. Although Helmholtz's instrument was of a crude construction, it does not lessen the fame of having opened an inexhaustible mine of inquiry; of having shed light on an heretofore chaotic

darkness, and of having completely revolutionized all preconceived notions of the diseases of the deeper structures of the eye. It is a striking fact, indeed, that the almost unparalleled strides ophthalmic surgery has made within late years, date, by a remarkable coincidence, with Helmholtz's immortal discovery.

The first improvement in the ophthalmoscope was made by Theodore Ruete of Leipsic, in 1852, by introducing a concave mirror as reflector, which had a small opening in the center for the observer's eye. Since then, mirrors of different shapes have completely superseded the plates of polished glass. Liebreich introduced a most handy and useful instrument. He used a concave metal mirror, about 1¼ inch in diameter, and of eight inches focal length. The back of the central small aperture is bevelled off towards the edge, in order that the peripheral rays of the cone of light, which passes through it, may not be cut off by a thick, broad edge, which would make the opening a short tube. Behind the mirror, which is fixed upon a short handle, is a small clip for holding a convex or concave lens. Other improvements were made by Coccius, who introduced a plane mirror, while Zehender made use of a convex one, in order to concentrate the light upon one point. A further step to perfection was made (1870) by E. G. Loring, a physician of New York; his instrument avoids the constant changing of lenses behind the mirror, as it contains the different convex and concave glasses in three rotating cylinders, alternately attached behind the mirror. In 1873, Dr. H. Knapp did away with Loring's cylinders by presenting an ophthalmoscope with two undetachable but revolving discs, one of which containing concave, the other convex lenses. These are arranged in such a manner that they rotate past each other, so that the focal value of each lens can be lessened to a greater or less degree by adding to it the various neutralizing lenses of the other disc. The glasses are covered by a stationary metal plate to prevent soiling. In 1874, Loring simplified the foregoing instrument, and by adding a few improvements produced a comparatively cheap and handy ophthalmoscope, which soon took the fancy of most oculists.

All these instruments are monocular; Dr. Giraud-Teulon, of Paris, and Dr. J. Z. Laurence, of London, invented binocular ophthalmoscopes by combining Helmholtz's invention with Wheatstone's stereoscope; but they soon were dropped, the more handy monocular instruments proving preferable.

The ophthalmoscope finds its greatest usefulness in the hands of expert oculists, who have all opportunities of learning how to use it. My first experiment with it was about twenty years ago. I had an instrument of Liebreich's, and my workman and some trusting friends were the innocent victims of my investigating proclivity; but they soon were frightened by the flashes of light which almost blinded them, as they were directed to look straight into the mirror, instead of looking a little sideways. Since then, there have been published several exhaustive treatise on the use of the ophthalmoscope, which should be carefully studied before attempting to employ it. It is not my intention here to specify the many variations and their correction in the observer's and the observed eye, as this treatise is written for opticians who, perhaps, never will professionally handle an ophthalmoscope. I, therefore, close this chapter with some generalities which may give the reader an idea of the great importance of Helmholtz's invention.

The ophthalmoscope reveals two important conditions of the eye; the *pathological*, by the indirect method, where we obtain, by placing a biconvex lens of about three inch focus in front of the observed eye, an inverted image of the disc; and the *optical*, by the direct method, not using the convex lens, when we obtain an upright image. The *indirect* method is mostly employed to ascertain the healthy or impaired condition of the inside structures of the eye; the strong convex lens before the eye greatly facilitates such an examination. By means of this method, experts discover the beginning of certain serious diseases, as for instance, Bright's Disease, before any other symptoms of it show themselves. The *direct* method, on the contrary, reveals the optical condition of the eye with great certainty, and shows the myopic, hypermetropic or astigmatic errors of the eye. We may

say, therefore, that ophthalmology is an exact science; in no other branch of practical medicine or surgery can an equally certain diagnosis be made. Some years ago I was introduced to one who pretended to know all about a person's general state of health and mind by looking at him without asking a single question; but, as ridiculous as were his pretensions, we have to bow to the expert oculist who accomplishes this feat by looking into the eye with the ophthalmoscope.

To make a professional examination we first have to adjust our own eyes to the focal distance of six or eight inches, by means of the convex or concave lenses in the revolving discs attached to the ophthalmoscope; then, when we place our eye at the given distance, and we find the retina sharply focused, the eye observed will be emmetropic. But when the image is indistinct, and we only can gain a clear view of it by changing our own correcting lens to a stronger one, there is hypermetropia present in the observed eye, and the difference between the two lenses is the amount of its ametropia. Again, when we have to reduce the power of our correcting lens to a weaker one, then the eye observed is myopic, and the difference between the two lenses represents the amount of myopia.

This result is only approximative, as the observed eye remains in full possession of its *accommodation*, which greatly interferes with the exact measurement of its refractive errors. In many cases it is necessary to suspend the power of accommodation by the use of a mydriatic before we can measure the exact amount of the *refraction*, as this is not affected by the application of the mydriatic. Some of my readers may not be posted about the difference between the accommodation and the refraction of the eye; it will, therefore, not be out of place to define in a few words their meaning. When the crystalline lens is in a state of rest it still has a certain amount of refractive power, which is, as the mathematician would say, "constant"; but as long as the lens is under the control of the ciliary muscle, its power of refraction is changed by the alteration of its convexity, it is "variable." This changing of its form or shape is

called "accommodation," and to suspend this "variable factor" in order to measure only the "constant factor," *the refraction*, it is necessary to apply the mydriatic.

As valuable, yea indispensible, as this instrument is to the medical faculty, it is of but small importance to the dispensing optician. It is not only difficult for us to find the many willing patients for experimental purposes in order to acquire expertness, but it is also a very unprofitable and time-losing business as long as patients refuse to pay for our trouble, in addition to the regular price of the spectacles we select for them.

## CHAPTER XIX.

### Second Sight.

The eye is by no means a perfect optical instrument. Its defects are, under ordinary circumstances, suppressed by the brighter and more perfectly formed central portion of the retinal image, so that the defects, when not of too high a degree, are unobserved and can only be detected by careful experiments. Helmholtz once remarked: "If an optician wanted to sell me an instrument which has all these defects, I should think myself quite justified in blaming his carelessness in the strongest terms, and give him back his instrument." And yet, nobody can devise a better plan for the construction of this organ to accomplish all its duties with such simple means. It is the most wonderful machinery ever designed, although it is not perfectly achromatic, and besides, suffers from spherical aberration. Yet, we have no reason to grumble at trifling imperfections; we ought to accept this precious gift of nature with reverential gratitude, and take proper care not to hasten unnecessarily its natural decline by an inconsiderate, reckless use. But the most careful use of our eyes cannot defer the senile changes which take place in all eyes, in myopic and hypermetropic as well as in emmetropic eyes, on account of the natural development of the crystalline lens.

In childhood the nucleus of the lens is firm, while the density diminishes toward its periphery; this arrangement almost entirely overcomes the spherical aberration, as the peripheral rays are less refracted than they would be, if all parts of the lens were of a uniform density. Hence, the circumferential rays are united at nearly the same point as the central rays; consequently, the child can have a very large pupil, and the peripheral rays still be united in the focus of the central ones. With the

advance of age, the outer layers increase in firmness; they gradually approach the consistency of the nucleus. The greater firmness and more uniform consistency of the lens causes it to become flatter, thus diminishing the refractive power of the lens, and increasing its spherical aberration. The peripheral rays are brought sooner to a focus than the central, thus compelling the pupil to reduce in size; the iris acting now as a diaphragm in a telescope.

The time for the use of spectacles has arrived, and should not be overlooked by those who wish to preserve their eyesight. The increase in the strength of spectacles will keep step with the gradual hardening and consequent flattening of the lens. The development of the crystalline can be compared to a fruit while growing; it takes its natural course till it is ripe. We cannot, directly, weaken the lens, no matter how long it is used; but, indirectly, it is impaired by the other parts of the eye which we abuse or hurt,—as the fruit is prematurely ripened by the sting of an insect. When we unduly postpone the use of spectacles, we do not weaken the lens, but the ciliary muscle, and when we overwork the eye, it is not the lens that suffers, but the retina. By an inflammation of the cornea or iris, the lens is only secondarily affected; choroiditis and retinitis have the same effect. Each suffering part acts sympathetically upon the others by reflex action.

One of the most dreaded affliction of the eye is when the lens commences to lose its transparency, when signs of cataract make their appearance, and people anticipate blindness and misery. Cataract is, generally, a disease of old age; the loss of the transparency of the lens is chiefly due to its deficient nutrition, dependent upon an inefficient blood supply, and consequent diminution of the watery constituents of the crystalline lens. Inflammation of the inner tunics of the eye, especially of the iris, choroid, and vitreous humor, may also give rise to cataract, not by an impairment of the nutrition of the lens, but by the inflammatory changes, implicating the inner capsule, and even the lens itself. — It is very difficult to detect the real cause of cataract. Among the

most important of these causes is exposure to light and heat; for instance, the artisan at his work-bench, facing with his unprotected eyes a window or gas-jet for many hours every day; the cook, bending over the heated range; glass-blowers, bakers, blacksmiths, puddlers, stokers and engineers are affected. A fully formed, mature cataract may be easily recognized even with the naked eye; the pupil is no longer dark and clear, but is occupied by a whitish opalescent body, which lies close behind it. However, when cataract is *incipient*, and but slightly advanced, more especially when the opacity commences at the edge of the lens, it may be overlooked, except when the eye is carefully examined with the ophthalmoscope.

Care must be taken not to mistake the physiological changes which occur in the lens in old age for commencing cataract. These changes consist in a thickening and consolidation of the lens substance, especially of the nucleus, which assumes a yellowish tint. The chief distinctive features between this and incipient cataract are, that in the former case the sight is perfect, when assisted by suitable glasses; the opacity remains absolutely or almost entirely stationary *for a long period*, and the cloudiness is not observable with the ophthalmoscope, except with oblique illumination. We have here a clear case of *second sight*.

Since the issue of my first book, I made diligent inquiry of several cases, and learned that their development is not of such short duration as I imagined. A former customer laid aside her spectacles at the age of 66 years, and is now, after 17 years, still doing fine needle-work as well as ever. Of course, her distant vision is poor, and ought to be corrected by concave glasses; but she hates to commence again with spectacles. Other cases, of a shorter standing, known to me, show that second sight is not always a gift of Danaus,* which ends in misery, but that it is sometimes a blessing, and a source of great rejoicing for those people who perceive that one

* Danaus was the king of the most prominent province in ancient Greece. It is told that his gifts were often disastrous to the receiver. A gift, therefore, given with bad intention, is called after him.

faculty after another gradually withers and vanishes, except their eyesight.

In the development of *real* cataract we meet with a phenomenon which may falsely be taken for second sight, and cruelly disappoints the afflicted, as it is, generally, of short standing. Dr. Soelberg Wells says: "The rate of progress of senile cataract is very difficult to determine with accuracy. Sometimes, years may elapse before it arrives at maturity. It may remain at an incipient stage for a long time without apparently making any progress, and then suddenly advance very rapidly, arriving at maturity within a few months or even weeks. We must, therefore, always be upon our guard against giving a decided opinion as to when any given case of incipient cataract will be fully formed. Patients are sure to ask this question, and we may fall into great mistakes by giving a decided answer." Another physician recently remarked: "When oculists, formerly, were consulted for relief from commencing cataract, it was their habit to acquaint the patient or his friends with the cause of the failing vision. The opinion expressed was to the effect, that for the present nothing could be done to restore vision; on the contrary, it would grow steadily worse, but that though blindness might and probably would ensue in one or both eyes, vision could be restored by removal of the *ripe* cataract. Thus the patient and the family were sent away with an abiding solicitude hanging like a cloud over the household, the anxiety alleviated only by the prospect of a future successful operation."

Such sensible remarks teach the wholesome lesson to opticians, who have to deal with those customers, seeing the advance of this fearful visitation, not to be indiscreet, and wantonly dispel their happy delusion, as nothing in the world can arrest the final course of their trouble. We may advise them not to read or sew at night, and to spare their eyes as much as possible. When in the first stage of incipient cataract bright light begins to annoy their sight, give them smoked glasses; they neutralize the scattered rays which pass through the infected lens. Do not lose patience by their renewed attempts to find relief by changing their spectacles. Have always a kind

word for them, and as you cannot help them materially, let them have the full benefit of your benevolent sympathy.

## CHAPTER XX.

### Relief to Injured Eyes.

This chapter is partly compiled from different sources. It would not have found a place here if it were not for the great usefulness of these simple directions in case of emergency.

Though the eyes are well protected and shielded by the forehead, the nose-bridge and the cheek-bones, they are nevertheless exposed to accidents caused by small flying objects; and although the eyelids are reliable safeguards to keep off any foreign intruders, they may be out-generaled occasionally when they are the least aware of any danger. Some injuries do not allow of any delay, and as medical assistance is not always to be had when mostly needed, I thought it proper to add this treatise not only for the personal benefit of my readers, but also for that of their friends and customers, who may in their trouble come running to the optician to give them relief. I was several times successful in this respect, and may say that I saved more than one eye from great annoyance and danger.

A very common accident is the flying of *mud*, *dust* or *insects* into the eye, which, by the closing of the eye, enter between the lid and the eye-ball. People thus affected generally keep their eyes closed, as the opening of the lids causes such an irritation that the eye-ball is soon inflamed and bloodshot. The quickest way to relieve these sufferers is to wash the dirt out with clean water by means of a camel-hair brush or a feather. This is done in the following manner: With our left hand we take hold of the eye-lashes of the upper lid, drawing it forward sufficiently to allow the brush or feather, previously dipped in water, to enter between the eye-ball and lid, till we reach the inner folds. We direct the patient to

look downward, and move the brush towards the nose, not to the outside. We have to repeat this several times with plenty of water. Then we depress the lower lid, directing the patient to look upward, and wash carefully as before, cleaning the brush after each application. In some trifling cases, when an insect or a few grains of dust have entered the eye, draw the upper lid as far down as possible, a little outward, and push the lower one as far up as you can. Then let the upper lid fly back to its natural position, when the eye-lashes of the lower one will act as a brush, detaching any light substances, and relieving the eye instantly. Make it a rule never to rub the eye when injured, as the irritation will be increased largely by it, and soon will cause inflammation. When hard pieces are imbedded in the tender parts of the conjunctiva, which cannot be removed by the brush, it is not difficult to remove them, if they are lodged in the lower lid, by means of a handkerchief or some small pincers; but it requires some skill to remove them from behind the upper lid. In order to accomplish this, we have to evert the same, which is done by taking a good hold of the eye-lashes and the edge of the lid with the left hand, then applying with the right hand a thin pencil or any other rounded object to the middle of the lid, and by depressing the pencil, at the same time swinging the left hand upward, the lid is everted and the inside exposed for examination. The patient is now directed to look downward, which brings into view the whole inner surface of the upper lid, and enables us to remove any foreign bodies, as grains of sand or bits of coal, yet sticking in the soft part of the tender tissues.

A somewhat singular advice, how to remove grit from the eye, was lately communicated by a railroad man. He says: " Most persons with grit or any foreign substance in the eye will instantly begin to rub the organ with one hand, while hunting for their handkerchief with the other. They may, and sometimes do, remove the offending substance; but more frequently they rub until the eye becomes inflamed, then bind a handkerchief around the head and go to bed. This is all wrong. The better way is not to rub the eye with grit in at all, but rub the *other*

*eye* as vigorously as possible, causing the offended eye to profusely shed tears by which the bit of sand or dust is washed out."

Mechanics are very often hurt by flying *particles of metal* while hammering or turning, and chips may strike and penetrate to some extent the front part of the eye. If these are of iron or steel, and not imbedded too deep, we may remove them by the use of a strong magnet. In case these chips have penetrated so deeply that the conjunctiva has closed over the entrance of the wound, it is necessary to consult a physician. Such wounds are not very painful at first, and the application of water or oil may be sufficient to allow us to wait even until the next day to look for relief. Any longer delay may prove fatal, as a neglect will surely result in a violent inflammation, if these particles are not removed in due time.

Another danger to the eyes is the splashing of *quick-lime* into them, causing sometimes the complete loss of sight. I myself was a victim of such an accident at the age of four years. Some workmen were slacking lime, and I was wondering how stones covered with water could boil. Wholly absorbed by this phenomenon, one mischievous boy gave me a push, and I fell headlong into the hot lime water, but was immediately rescued, washed and brought to bed. I soon felt that something soothing was applied to my eyes, which relieved them of the burning sensation. It was three weeks before I could open my eyes again, and I remember quite well the many anxious inquiries of my parents, whether I could see them. In such accidents, the lime should be instantly washed out with large quantities of weak vinegar and water as thoroughly as possible, and a rag saturated with sweet-oil applied, till a physician can be consulted.

If *corrosive pigments and acids* enter the eye the whole face, eyes open, should be repeatedly dipped in water in order to dilute and wash off the acid or paint; then apply milk freely, and afterward plenty of oil, till medical assistance can be procured. Whatever is done must be done quickly, as it is of the greatest importance to relieve the eye instantly from the ravages of such corrosive substances.

In case the eye should be *scalded* or injured by the spattering of hot fluids, do not apply water, but only oil or milk, and shut off light and air by a compress of soft linen, thoroughly saturated with sweet-oil, till the doctor comes. — Hot vapors of strong sulphuric or nitric acids will cause immediate blindness if they strike the eye.

These directions are not intended to do away with the services of the physician. On the contrary, they are intended only to prevent as much as possible the pernicious consequences and further progress of such accidents, till professional aid can be procured. Sometimes five minutes' delay may destroy the eyesight forever, when by the prompt application of water, vinegar, milk or oil, the effects of such injuries would be diminished, and oftentimes removed entirely.

## CHAPTER XXI.

### Artificial Human Eyes.

Long before the Christian era, artificial eyes were used in statues and busts; they were made of colored stones or metal, and inserted into the cavity expressly constructed for their reception. The deep sockets found in some statues without eyes are an evidence of this; like that of Antinous in Paris, and others in different archæologic museums. In some ancient statues the eyes were outlined by the chisel and then painted. We have no record that glass-eyes were ever used for this purpose, although colored glass was already known at that period, and the story that mummies with artificial eyes were exhumed is probably without foundation. It was absolutely unnecessary to ornament a body which was enveloped all over, several inches thick with bandages, and then covered hermetically with a kind of plaster or cement. This outside coating was made to represent a human-like figure, studded with glass beads and other ornaments; but no mummies have yet been found with artificial eyes, except those lately discovered in South America, which are of modern date, only four or five hundred years old, of the time of the ancient Incas of Peru. The custom of embalming was very common among the Incas, and was made unusually easy by the warm, dry climate of Peru. It is stated that the embalmed were often simply placed in a sitting posture on the vast nitre beds, and left exposed to the open air. For years after death they were visited by friends and relatives, and it was consequently important that the semblance of life should be maintained as perfectly as possible. They removed, therefore, the perishable natural eyeballs of the dead, and substituted the dried eyes of the cuttle fish, which are almost indestructible, and possess sufficient warmth and fire to partially simulate life.

The substitute for a live human eye is not older than three hundred years. We find the first authentic record of them in the Chirurgical Work of Porrée, 1582, with drawings of two kinds of eyes, one to represent the eye and the lids, in case both were removed, the other to be used when the lids were still present, and to be inserted behind them. Both kinds were made of flat or slightly curved gold, silver or copper plates, enameled and painted to imitate the other eye as near as possible. When the eyeball and lids were totally removed by the operator, as was done very often at that time, the plate had to be large enough to represent also the eye-lids, lashes and caruncle. To this plate was attached a spring covered with leather, which encircled three quarters of the head, thus pressing the plate towards the hollow orbit. This was indeed a very poor commencement of that great benefaction of to-day. Porcelain, and afterwards glass, soon took the place of metal, as Fabricius states, in 1623. From that time the manufacture of eyes has slowly but constantly improved. Dr. Mauchard, 1749, relates of a lady who had been furnished by him with an artificial eye, that she only wondered why she could not see with such a beautiful imitation.

Since 1770, the eyes have been made of enamel instead of glass, mostly in France, and for many years, up to recent date, the best eyes have come from Paris. Some of the celebrated manufacturers were Hazard-Micault, Noël, Boissoneau, etc. But at present good eyes are made everywhere, even in America. The best eyes I ever handled were made by Ludwig Müller-Uri, in Germany, who lately died.

An artificial eye is a shell of enamel, representing the front of the eyeball, the loss of which it is intended to conceal. They are so perfected that nobody can distinguish them from the natural eye, and they are now used by everybody who possibly can afford to pay for them. An artificial eye is by no means a luxury as in former years, when only rich people could afford to pay its price, but it is now altogether a *necessity* for everyone who is unfortunately disfigured by the loss of it. The several functions it has to perform, are:

1. *The artificial eye serves as a beautifier.* It restores the natural appearance of the face and preserves the regularity of the features. If, for instance, the greater part of the eye-ball is lost, the lids have no support and, consequently, shrink and shorten. When this loss happens in the earlier stage of life, the development of that side of the face becomes retarded and will present a strange appearance. Even in adults this shrinkage takes place after the lapse of a few years. It is, therefore, wrong to postpone the use of an artificial eye, especially with children whose tissues change so rapidly, the more so, as even a child of five years can wear an artificial eye without any inconvenience.

2. *The artificial eye serves as a remedy.* It enables the eyelids to move freely, they can be closed and opened as before, and also restores the functions of the tear-passages. After the removal of the eyeball there is an empty space left behind the lids; the tears accumulate in this cavity, and irritate the edge of the lower lid, and frequently give rise to ulceration. By means of an artificial eye, however, the tears are directed to their natural channel, and are removed in the usual way through the nose. It also prevents the eyelashes from turning inwards, causing inflammation and suppuration by their constant friction upon the structures left behind in the socket. It protects the latter from all outside irritation, such as wind, dust, smoke, etc., which otherwise might sympathetically exert a pernicious influence upon the remaining sound eye.

3. *The artificial eye is a real benefaction.* It is a blessing to everybody, for the rich as well as for the poor; but while it serves the former mostly as a beautifier, it very often protects the latter against want and misery. It is really a question of existence for them, as some employers will hesitate to engage a person thus disfigured; or trust him with work that requires good sight, even if it could be well performed with only one eye. By the use of an artificial eye, however, such objections are removed and he may readily find employment.

A judicious selection of the different sizes of artificial eyes depends altogether upon the various dimensions of the cavities. Children, generally, need larger eyes than elderly persons, and a great variety as to shape and color is, therefore, necessary to suit all cases. The white of most artificial eyes is on one edge more or less cut out, and as a rule, this edge should be used for the upper lid, in order to allow the same as much room and liberty of motion as possible. We may classify the eyes, therefore, into *right* and *left* ones, according to the position of this cut-out. By doing this, we must bear in mind that the smaller end of the eye is the nasal part. But when the artificial eye squints upward, we have to change this rule, as the true position of the pupil and iris is the principal condition of a good fit. The eye should never cover the caruncle (the fleshy protuberance in the inner canthus, or in the corner of the eyelids near the nose), and should allow the lids to close.

In order to make the artificial eye light, and save the under lid from being depressed by its weight, it is made in form of a shell with its border finished off by the melting process with a pointed flame. Any alteration by cutting and polishing it, will render the eye useless after a short while.

Before the insertion of an artificial eye, the tissues in the socket must be perfectly healed and cicatrized, and the conjunctiva free from inflammation and morbid sensibility. An artificial eye, besides resembling the opposite sound eye in prominence and in color and appearance of the iris, ought, if the stump be good, to move in concert with it. This it does by following the motions communicated to the conjunctival folds, into which its margins are fitted, and by the movements of the stump. It ought at the same time to cause no pain or uneasiness. A perfect motion of the eye is possible only when the stump is large, and the eye is almost resting on it. For this purpose the eye must be rather flat, not too large, lest the free motion will be checked by its touching the sides of the orbit. When the stump is small, the artificial eye must be large, high and well rounded. The inner folds of the eyelids are then its only support, and its

motion is, of course, little and insufficient; the more so, if the patient insists on having the artificial eye matched exactly in size with the other, thus producing a "staring look."

To *introduce* an artificial eye, it is necessary to raise the upper eyelid and slide the eye, previously dipped in water, up behind it by the end which is to correspond to the temporal angle. Then turning the nasal part upward, and letting the upper eyelid fall, depress the lower forcibly, and make the lower edge of the artificial eye slip into the lower palpebral cavity. This being done, and the lower lid allowed to rise, the introduction of the eye is accomplished.

The *removal* of an artificial eye is done in the following manner. It is withdrawn by an opposite procedure, by depressing the lower lid, and inserting the curved end of a hair-pin, or even the thumb-nail, between the eyelid and the lower edge of the artificial eye, thus hooking it out from the lower palpebral cavity, when it will glide down from behind the upper eyelid, and fall into the hand ready to receive it. In doing this himself, the patient should lean his face over a soft cushion, or the like, in order that, if the eye should slip out of his fingers, it may not be broken in the fall.

The artificial eye is withdrawn every night, and is to be cleaned with water (which should be tepid in winter) of the mucus which may adhere to it. Before putting in the artificial eye and after withdrawing it, the patient should bathe the cavity of the orbit and the stump of his eye with water. A thorough cleaning of the artificial eye every week with soap, water and a soft sponge is also recommended in order to remove all fatty matter from it. But altogether objectionable is the habit of some people to oil their artificial eye before inserting it, because the mucous membranes of the orbit do not require such additional lubrication, as long as the eye has not lost its polish.—In the course of time it becomes rough from the slow corrosive action of the humors which come in contact with it, and requires to be exchanged for a new one. In case there should be some difficulty in procuring a new eye, the old one may be *repolished*

and do service for a few months longer. You take a rag of cotton, form it into a small ball and fasten the eye over it with soft bee's wax. The inside of the eye should be well filled up to prevent any accident. Then put in your hand a little alcohol or water and fine pulverized English rouge, and afterward Parisian rouge to finish, and shine the eye as you would shine a brass button.

A worn-out eye causes congestion of the lids, a swelling of the conjunctiva and a gradual filling up of the orbit. Many unfortunate sufferers have in this way deprived themselves entirely of the great blessing of correcting their disfiguring loss by a suitable substitute. As an artificial eye is liable to be broken by accident, a person making use of it should always have several on hand. An eye will last no longer than two years on an average. From the irritation excited by the artificial eye, when it is either a bad fit or worn too long, the palpebral conjunctiva are apt to become much congested, and beset with polypus-like excrescences. In this case the use of the artificial eye should be discontinued for some time, and it is necessary for the patient to seek medical assistance.

## CHAPTER XXII.

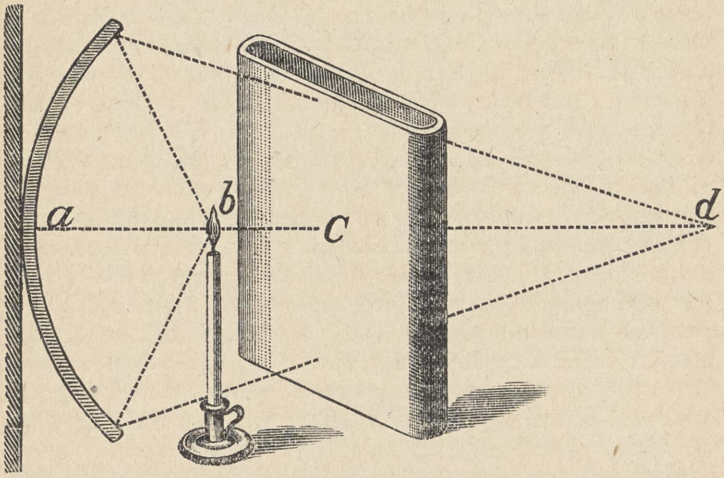
### Caloric Rays in Different Lights.

According to the old emission theory, light is a compound *matter*; but according to the new undulatory theory, it is a compound force. It is a mixture of luminous and caloric waves, and is also a combination of the different colors. To resolve light into its colors has been a comparatively easy task since the properties of the prism have been known; but the complete separation of luminous from the caloric rays is yet a matter of investigation. Eminent scientists have labored long to isolate one from the other, but only with partial success. Light, passing through an ice block, or through plates of mica, is not deprived of its caloric rays, although they are absorbed to a certain extent by reflection; but by means of a strong burning-glass we detect enough of them to be aware of their presence. Some explorers have succeeded in completely absorbing the luminous rays, and showing the presence of only the caloric rays in their full strength.

The following experiment was communicated to me by Professor Pepper, of England, in 1872, when he, on his lecture tour, passed through New Orleans. I repeat it here as he explained it to me. I have never tried this experiment myself. I remember with great pleasure his able lecture on "Light and Heat," illustrated profusely by novel and highly interesting experiments.

The candle *b* stands between the glass-jar *c* and the concave mirror *a*. The rays of the candle are thrown by the mirror on the flat jar, filled with a solution of *sulphuret of carbon and iodine*, which completely absorbs the luminous rays. You cannot detect through the jar the least trace of light; but if you hold your finger at the point *d* you will find that the caloric part of the light is

concentrated there most keenly. This shows that the liquid absorbed only the luminous rays, and allowed the caloric rays to pass through without perceptible interference.




In the same manner that luminous rays are modified or intercepted while passing through bodies of different degrees of clearness, the caloric rays are also more or less intercepted by different substances. Mica, for instance, absorbs the greater part of the caloric rays; but the only substance which allows all caloric rays to pass without any obstruction is clear *rock-salt*. Experiments with prisms of this salt have demonstrated the fact that light passing through such a prism gives two spectra, one by the luminous, another by the caloric part of the light, with the remarkable difference that the *red* line of the caloric spectrum is as broad as all the other colors combined, from orange to violet. This experiment is an undeniable proof that the caloric and luminous rays can be separated, and that both kinds of rays are subject to the same law of nature, the undulatory or wave theory.

This theory defines light as *motion* of such an intense velocity that we can express it only in figures, but are utterly unable to comprehend it. Imagine that we were able to build a machine of indestructible material, and had the power of increasing its revolutions indefinitely.

We put it into operation. As long as we can follow its movements with the eye, we have *common motion*. We can follow with our eyes a stone thrown to some distance. This also is common motion. Let us now increase the speed of our machine thirty-three revolutions a second. The eye can no longer follow it, but the ear discerns a low hum, which becomes louder and higher as the machine gradually moves quicker. We have *sound*. A rifle-ball is not seen, but we hear its whistling noise. When the tone has reached its highest pitch (38,000 vibrations in a second), our ear is unable to perceive any further increase; we feel then the effect of *heat*, and soon see a violet glimmer, then a transition through blue, yellow and red into white. We now have *light*. The vibrations have increased to many thousand billions a second. If our machine is not melted by this time, and is still running with increasing speed, we had better keep at a safe distance, for the next action will be the emission of *electric* sparks and lightning in all directions.

Here science ends, and here is the limit of all power and force we can explain or comprehend. But if we allow our imagination its widest range, and look upon this experiment only as the symbol of the universal, sublime power, does it not give us a faint idea of the proper mode of attaining to the knowledge of the *ultima ratio*, the incomprehensible omnipotence?

Light and heat are always combined; there is no light without heat, for phosphorescence cannot be regarded as light. Of all the lights in existence, the natural or *sunlight* is the most pleasant; it has 70% of caloric and 30% of luminous rays. The great preponderance of the caloric over the luminous rays is necessary to make our earth habitable, as its natural heat, about one hundred feet below the surface and not interfered with by atmospheric changes, is only 50° Fahrenheit. Although the temperature increases 1° for every 65 feet of depth, so that at two miles below the surface water will boil, and at thirty-four miles, iron will melt; the inner heat, estimated at more than 10,000°, is not able to warm the comparatively thin crust of our earth much above the freez-

ing point. Besides, if the sun would not come to our assistance, we could not endure the low temperature of the Universe, which is calculated to be 2000° below zero. But the sun with her 100,000° of heat on her surface, overcomes all these obstacles, and sends us sufficient light and heat to make our earth the most pleasant quarters to live in.

We must not form the wrong idea that the immense radiating heat of the sun could extend through the whole solar system and reach the last planet, Neptune; in fact, it does not reach even the nearest planet, Mercury.*— The real size of the sun can be best demonstrated by supposing the sun to be a hollow shell, with our earth in its center and the moon moving around the earth at the same distance. Now, if we imagine ourselves to be present on the surface of the shell, and looking at the moon through a hole, it would in its nearest position to us appear only of the same size as when viewed from the earth. Just think, the sun to be a solid body with a diameter of four times the distance of the moon from the earth, and you have an idea of its enormous size. And, further, imagine this immense ball to be in a state of combustion! Not calmly glowing as it appears to us from a distance of 95 million miles, but in a state of furious uproar and thundering convulsions. Just look at a large house on fire, and notice the crackling and hissing of the flames; watch with awe the fearful roaring and thundering of a burning city; picture to yourself, if you can, the terrific reports and unearthly glare when a stream of lava bursts through the sides of a volcano; the vast flames leaping hundreds of feet into the air, amidst the fearful internal rumblings; multiply all these a million times, and we may get a faint idea of the sun's present condition. The terrible roaring would be heard millions of miles away; tremendous sheets of flames, called protuberances, are thrown hundred thousand miles into space; the constant explosions, tearing holes in the surface of the sun, causing the sun-spots, which our earth would not fill: really, a battle of elements of the sublimest grandeur.

* We know too little of the planet, Vulcano, lately discovered, to use it here as an illustration.

The atmosphere of the sun is calculated to extend about five million miles, but its radiating heat will not reach thus far, so that the planet, Mercury, whose mean distance from the sun is 37 million miles, must have at least thirty million miles of that extreme low temperature of the universe, and our earth fully 90 million miles of it. It is, therefore, impossible that the rays of sunlight actually carry particles of its radiating heat with them. In fact, the vibrations of ether caused by the sun are by themselves neither light nor heat, until they are decomposed under certain conditions, as in passing through our atmosphere; but how this is performed I must leave to professional scientists to explain.

The sunlight is perfectly white or colorless, and is the most agreeable to the eye. The caloric part of it is greatly modified by the moist atmosphere it has to penetrate, and by repeated reflections. The healthy eye is well able to bear its effect the whole day long without fatigue.

Next to sunlight, *electric light* is the strongest; it has a bluish-violet tinge, and contains 80% of caloric and 20% of luminous rays. The electric light is not produced by combustion, as we have seen in sunlight, but by the intense heating and volatilization of ponderable matter, because the electric spark cannot pass through a vacuum. It is very intense, so that the eye is dazzled, and vision becomes much more indistinct than with a light of the same power given off from a lamp with a large circular wick.—The first experiments with large Voltaic piles to produce an electric spark, were made merely for curiosity's sake, till in 1813, Sir Humphrey Davy (1778—1829), a celebrated English chemist, attached to the wires of the different poles, pencils of charcoal, and produced a constant arc-light of considerable strength. But his experiment was not followed up as arduously at the time as it has been during the last twenty-five years. The scientists experimented with the Drummond or calcium light, and later with Bunsen's magnesium light, without following up Davy's temporary success. In fact, it was merely an experiment and of

no practical use, as the charcoal points were too rapidly consumed. A great improvement was made in 1843, by Foucault, who substituted pencils of hard gas-carbon, such as is deposited in the interior of the retorts during the manufacture of illuminating gas. Since then, many different forms of electric lamps have been devised. They are divided into two kinds: the *arc-lamp*, for street illumination, and the *incandescent*, for use in houses, offices and theatres. The latter is an invention by Thomas A. Edison. This light is preferable to gaslight on account of its cleanliness and its comparative coolness; it does not fill the room with impure vapors, is steady and pleasant to the eye.

An important improvement in the line of illumination was, at the time, the invention and introduction of *gas-light*; it has only 90% of caloric rays, has a yellowish tinge, and is often flickering and unsteady and, therefore, tiring the eye more than an improved oil-lamp. Gas is made from different combustible materials, of which the stone-coal is mostly employed. Just one hundred years ago, 1792, Murdoch made the first experiments with it; and already in 1811 some stores and streets in London were illuminated with gas. Simultaneously Lampadius experimented in Germany, and Lebon in France, but with little result; the English were far ahead in the manufacture of gas, mostly due to their superior coal. Especially after they engaged the services of the German chemist, A. Winzer (Winsor), the gas-industry made rapid progress. He collected the gas in large reservoirs or tanks, and thence forced it through small gas-pipes to the different places of consumption. He started many gas-companies in England as well as in France. He died 1830 in Paris. Between 1830 and 1840, almost all large cities had their gas-works, even in America.

Another useful light is the ordinary *oil-lamp*, with its 87% of caloric and 13% of luminous rays. The best form of it is an imitation of the German student's lamp, with a suitable shade; its light is preferable to all other

artificial lights. — Lamps were known in very ancient times, and are already mentioned in Gen. 15, 17, and Ex. 27, 20. The lamps of the Jews, Greeks and Romans, were of a primitive construction; a hollow open vessel for the reception of oil, ending in a spout to carry a coarse wick, was the whole arrangement, though the exterior was often artistically sculptured.

The real improvement of lamps began only in 1550, when Hieronymus Cardanus constructed a lamp with a separate receptacle for oil, which was attached to the side of the lamp, and which produced a comparatively steady light. Soon the addition of a lamp-shade followed. The next important improvement was made by the Frenchman, Leger, who invented, 1765, the *flat wick*, which was in 1782 improved into the circular form by Argand, who also added the glass chimney to the lamp. — The great trouble with all lamps was, that a bright light needed more oil than the wick was able to conduct to the flame, thus causing the wick to coal and compel frequent clipping. For this reason, Carcel (1800) combined a clockwork with the lamp to feed the flame sufficiently with oil. In 1809, the so-called "Astral-lamp" was introduced, which received its name from the round oil-receptacle placed below the flame; all lamps, heretofore, had their oil-vessels either sideways or above the flame.

A complete change in the construction of lamps was caused by the introduction of *petroleum*, or coal oil, as a light producing agent, which generates combustible vapors at a much lower temperature, and being a thinner fluid than other oils in use, it moistens the wick quicker and follows it to a greater height. But such a flame requires a good ventilation, which serves also to cool the burner; at the same time, the oil-fount has to be placed far beneath the flame to prevent the heating of the oil. When the wick is flat, the burner is in need of a semi-spherical metal cap with a slit, a little larger than the opening in the wick-guide, to allow a free passage of the flame, and where its vapors unite with the oxygen of the air, which favors a better combustion and prevents the flame from smoking. When the wick is circular, the metal cap is

replaced by a chimney, where the wider lower part is suddenly reduced into a smaller cylinder, while the chimney of the flat wick is bellied.

Another source of light is the *candle*, which has nearly the same proportion of caloric and luminous rays as the lamp. Candles were not known before the second century after Christ, although lamps were used for over two thousand years, before anybody conceived the idea that solid fatty matter, like tallow and wax, would answer the same purpose. Candles have the advantage that they do not smoke as much as the oil-lamps, but are more expensive, especially the wax-candles. For many hundred years they were used only in churches on certain solemn occasions, and by the rich and reigning households as a sign of luxury. — About the year 1700, the spermaceti-candles were introduced; their light was extremely white, but the price was considerably higher than even wax-candles. The spermaceti is a fatty substance from the head of the cachelot ( potfish or white whale); sometimes one single fish produces twelve barrels. Such candles were mostly used to compare and measure the intensity of different lights, but were too costly for every day use. Since 1725, the cheaper stearine-candles have been great rivals of the still crude lamps of that time, especially since the invention of braiding the wick, although the improved lamps gradually superseded the candles, accomplished finally by the introduction of coal-oil. In 1831, De Milly invented a simple and cheap method of producing stearine; the manufacture of candles was again greatly revived, but their most successful rival is now the gas. The poorest light of all is the alcohol-lamp, which has only ½% of luminous rays, and is absolutely unfit for seeing-purposes.

It now remains to draw attention to the action of the different lights upon the eye, and to show the importance of knowing the exact proportion of the luminous and caloric rays in either of them. We have seen in a previous chapter that the size of the pupil is governed by the action of the iris, and as the iris is affected only

by luminous rays, it is evident that light which contains the largest proportion of them will contract the pupil more than another light with less luminous rays. The 30% luminous rays of the sunlight will, therefore, contract the pupil most, and will allow but a limited amount of caloric rays to enter the eye. Any light with a less proportion of luminous rays causes the pupil to dilate, and favors the entrance of a greater amount of caloric rays without improving sight. Therefore, the large quantity of caloric rays in all artificial lights will sooner fatigue the eye than the comparatively cool sunlight. If we visit, for instance, a well-lighted theatre during a "matinee," and there are exposed for hours to the dazzling gaslight, we feel greatly relieved when sunlight again strikes our eye.

# CHAPTER XXIII.

## Range of Vision.

In Genesis, chap. 11, 1—9, we find the amusing story of the building of the Tower of Babel, "whose top may reach unto heaven, and may be seen upon the face of the whole earth." People were afraid to stray away too far from the center of their colony, partly for fear of being lost in this wide world, but mainly for fear of tumbling down, somewhere, over the edge of the flat circle, which the ancient believed the true shape of the earth.

The first one who showed practically that the earth is a globe, was Christopher Columbus (1435—1506)*, who maintained that by sailing westward, one would reach the East-Indies sooner than by the south-east course round Africa. He explained his plan, after many previous failures in Italy and Portugal, to Ferdinand and Isabella of Spain; but only after an eight years' struggle with the obstacles thrown in his way by ignorance and malice, especially by the fanatical priests of the Spanish Inquisition, he received three small vessels with 120 men. Eighteen years had elapsed since he first conceived the idea of his enterprise. Most of that time

* Columbus was of an engaging presence, tall, well formed and muscular, and of an elevated and dignified demeanor. His visage was long, his nose aquiline, his eyes light-gray, and apt to enkindle. His whole countenance had an air of authority. Care and trouble had turned his hair white at thirty years of age. He was moderate and simple in diet and apparel, eloquent in discours, engaging and affable with strangers, and of great amiableness and suavity in domestic life. His temper was naturally irritable, but he subdued it by the benevolence and generosity of his heart. Throughout his life, he was noted for strict attention to the offices of religion; nor did his piety consist in mere forms, but partook of that lofty and solemn enthusiasm, with which his whole character was strongly tinctured. Of a great and inventive genius, a lofty and noble ambition, his conduct was characterized by the grandeur of his views and the magnanimity of his spirit. The treatment which he finally experienced from the Spanish court shows that ingratitude is not confined to Republics.

had been passed in almost hopeless solicitation, amidst poverty, neglect and ridicule; the prime of his life had been wasted in the struggle, and, when his perseverance was finally crowned with success (Oct. 12th, 1492), he was about 56 years of age.

Since the real shape and size of our earth is known, we are able to estimate the longest distance at which we can see an object, either with the naked eye or with the assistance of a spy-glass or telescope; because the range of vision is not dependent only on the acuteness of vision, or on the optical strength of an instrument, but is limited also by the curvature of the surface of the earth. It is well known to all engineers that, on an even plane, only the head of a man is seen through a field-glass at the distance of three miles, and that, in order to see at a longer distance, either we have to take a higher stand, or the object must be raised to a greater height. Lighthouses are erected on this principle; the farther their light is to be seen, the higher they must be built, as ships have only a limited height. The following table shows both, the distance and the height at which a light can be seen.

| | | | | | | |
|---|---|---|---|---|---|---|
| At | 5 | miles, | the light must be | | 15 | feet high. |
| " | 10 | " | " | " | 60 | " |
| " | 15 | " | " | " | 140 | " |
| " | 20 | " | " | " | 250 | " |
| " | 30 | " | " | " | 500 | " |
| " | 42 | " | " | " | 1000 | " |

The rule for calculations of this kind is: "The curvature of the earth is taken to be *eight inches* for the first mile, and increases according to the square of the distance." For instance:

| | | | | | | |
|---|---|---|---|---|---|---|
| 2 miles, | $(2^2)$, | $4 \times 8$ | inches | $= 32''$ | or $2\frac{2}{3}$ | feet. |
| 3 " | $(3^2)$, | $9 \times 8$ | " | $= 72''$ | " 6 | " |
| 4 " | $(4^2)$, | $16 \times 8$ | " | $=$ | 10 | " |
| 5 " | $(5^2)$, | $25 \times 8$ | " | $=$ | 16 | " |
| 10 " | $(10^2)$, | $100 \times 8$ | " | $=$ | 66 | " |
| 15 " | $(15^2)$, | $225 \times 8$ | " | $=$ | 150 | " |
| 20 " | $(20^2)$, | $400 \times 8$ | " | $=$ | 266 | " |

The less height of lighthouses, as shown in the first table, is due to the elevated stand of the captain on

board the ship, which is supposed to be ten feet from the waterline, thus allowing the light to be somewhat lower.*

*Range of vision*, practically, means "the distance at which we are able to see." On a plane surface, our vision is limited to three miles for all objects not higher than six feet; trees, towers and mountains are seen at a longer distance according to their height. But it is not only the *height* of an object that makes it visible, also its *width* must cover a certain space; besides, it makes a great difference if the atmosphere is clear or misty; if our eye is emmetropic or myopic; or if one object is more readily distinguished from its surroundings than another. The old rule that the width of an object must cover, at least, a visual angle of forty seconds, is superseded by Snellen's experiment with his test-types; and instead of seeing an object, which is not farther away than 5000 times its diameter, we have to shorten the range, according to his rule, to 3437 times. (See Chap. XII.) Thus we can find, approximately, the distance of any object, if we know its size; or its size, if we know its distance. The breadth of a man, on an average, is eighteen inches ($1\frac{1}{2}'$); if we can barely see him, he is $3437 \times 1\frac{1}{2}'$ away, or almost one mile. If he is dressed in white, and the surroundings are dark, the distance may be set at $1\frac{1}{4}$ mile; if dressed in black, it may be only half a mile.

If the back ground is dark, the impression of the different colors upon our eye range in the following order: White, yellow, orange, red, green, blue, violet and black, *i. e.*, black disappears first, then violet, etc. White on black makes the strongest impression, and is seen the farthest. Upon a light-colored background the effect is the reverse, with the exception of violet, which disappears before red.

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* There is an analogy of the above rule in the calculation of the decreasing strength of light, when gradually removed from us; it also loses in power just in proportion to the *square of the distance*. The intensity, which a light has at one foot from us, diminishes in strength four times at two feet, and nine times at three feet. It requires, therefore, nine candles, three feet off, to produce the same amount of light as one candle produces at the distance of one foot from our eye.

It is a well-known fact that all animals of prey bear the color of their hiding places. This enables them to surprise their booty without being seen from any distance. The striped tiger in the Indian swamps or jungles resembles the environs so perfectly that his victim is not aware of its presence till it is too late. The yellow stems of the reeds, and the darker ground, produce a striking resemblance to the skin of this voracious beast. This curious play of nature is called "mimicry," and benefits not only those beasts, but also many animals which are preyed upon.

The hunter is thus sorely vexed, and often cannot make use of the above rule. But in military life there are many occasions where it is of an immense importance, by furnishing an estimate of the number of the advancing foe, and giving time to prepare for their reception.

There arises another question analogous to the previous one. I refer to the fact that it is not difficult to judge with any certainty the number of people congregated in large assemblages. The easiest way of this kind of calculation is to measure the ground in square feet, and divide the number by 4, as four square feet is ample room for a standing person. We can measure a space by walking over it and counting the steps. A full step (not a stride) measures on an average $2\frac{1}{2}'$. Suppose, at a public meeting well attended, the bulk of the crowd extends in one direction 60 paces (150'); in another, 30 (75'); we have then $150 \times 75 = 11,250$ square feet, divided by 4, gives 2812; and with the stray people counted in, we may estimate that about 3000 people were attending the meeting. The next day we read in the different papers that the attendance was immense, and that there were at least 5000 persons present. Others may exaggerate the number even to 10,000.

## CHAPTER XXIV.

### TEARS.

The eyes of all vertebrates, with the exception of fishes and those amphibious animals that live in water, are provided with tear-glands, to moisten the surface of the eye and the inner side of the lids. If the tears were stopped, the outside of the eyeball would become dry and opaque, and sight be lost. As long as the tears flow they are drained through the tear-duct into the nose, and here mostly evaporate without any further annoyance. But, if in consequence of catarrh or any other cause, these tear-ducts are closed, the eyes fill with water which runs down the cheeks in the form of tears. This occurs in the eyes of animals as well as of men, but we cannot call it "weeping;" it is only due to local causes.

No animal weeps. Real weeping presupposes *mental emotion*, based on self-consciousness. Only human beings can reflect upon their own existence, and contemplate themselves in an objective way. Without this great superiority over animals, we would be unable to touch that responsive chord of our spiritual existence which makes us weep for joy, grief or pain.

Weeping* is synonymous to crying. Infants, when suffering even slight pain or discomfort, utter violent and prolonged screams; their eyes are firmly closed, so that the skin round them is wrinkled, and the forehead contracted into a frown. The mouth is widely opened with the lips retracted in a peculiar manner, which causes it to assume a squarish form. The firm closing of the eyelids and consequent compression of the eyeball, serves to protect the eyes from becoming too much

* The verb "to weep" comes from Anglo-Saxon *wop*, the primary meaning of which is simply "outcry." — "Expression of Emotions in Man and Animals, by Charles Darwin, 1873."

gorged with blood. The contraction of the muscles (corrugator supercilii) surrounding the eye produces the transverse wrinkles across the forehead, whilst the contraction of the *pyramidal muscle* (pyramidalis nasi) causes the eyebrows to be drawn downward and inward, producing a frown.* The muscles surrounding the eyes are somewhat connected with those of the upper lip; if, therefore, the former are strongly contracted, those of the upper lip likewise contract and raise the lip. Even in grown persons, it is observed, that when tears are restrained with difficulty, as in reading a pathetic story, it is almost impossible to prevent the various muscles, which with young children are brought into strong action during their screaming-fits, from slightly twitching or trembling.

Infants, while screaming, do not shed tears or weep until they have attained the age of three or four months. This fact is most remarkable, as, later in life, no expression is more general or more strongly marked than weeping. When the habit has once been acquired by an infant, it expresses in the clearest manner suffering of all kinds, both bodily pain and mental distress, even though accompanied by other emotions, such as fear or rage. With adults, especially of the male sex, weeping soon ceases to be caused by, or to express, bodily pain. This may be accounted for by its being thought weak and unmanly by men. The insane notoriously give way to all their emotions with little or no restraint; and it is observed that nothing is more characteristic of simple melancholia, than a tendency to weep on the slightest occasions.

Weeping seems to be the primary and natural expression of suffering of any kind. But common experience shows that a frequently repeated effort to restrain weeping does much in checking the habit. On the other hand it appears that the power of weeping can be increased through habit. A single effort of repressing tears is mostly ineffective; indeed, it seems often to lead to an opposite re-

* The pyramidal muscle is the fleshy part at the root of the nose, just in the straight line between the eyes, and is the chief support for the nose piece of Fox's eyeglasses.

sult. An old physician once remarked that the only means to check the occasional bitter weeping of ladies who consulted him, and who themselves wished to desist, was earnestly to beg them not to try, and to assure them that nothing would relieve them so much as prolonged and copious crying.

The principal function of the secretion of tears is to lubricate the surface of the eye; also to keep the nostril damp, so that the inhaled air may be moist, and likewise to favor the power of smelling. But another important function of tears is to wash out particles of dust or other minute objects which may get into the eye. That this is of great importance is clear from the cases in which the cornea has been rendered opaque through inflammation, caused by particles of dust not being removed, in consequence of the eye and eyelid becoming immovable. The secretion of tears from the irritation of any foreign body in the eye is a reflex action; that is, the body irritates a peripheral nerve which sends the impression to the lachrymal glands. These glands cause the relaxation of the muscular coats of the smaller arteries, which allows more blood to permeate the grandular tissue, thus inducing a free secretion of tears. When the small arteries of the face, including those of the retina, are relaxed under very different circumstances, for instance, during an intense blush, the lachrymal glands are sometimes affected in a like manner, for the eyes become suffused with tears. Cold wind, smoke, or a blow on the eye, always causes a copious secretion of tears. The glands are also excited into action through the irritation of adjoining parts; thus when the nostrils are irritated by pungent vapors, though the eyelids may be kept firmly closed, tears are secreted. Strong light has a tendency to cause lachrymation, especially when the eyes are diseased; the retina and cornea become excessively sensitive to light, and exposure even to common daylight causes forcible and sustained closure of the lids and a profuse flow of tears. When persons who ought to begin the use of convex glasses habitually strain the waning power of accommodation, an undue secretion of tears often follows. Children and silly persons very often cry

because they set great value on trifling objects, whose refusal makes them extremely unhappy.

Weeping is not always a sign of weakness, or an act to be ridiculed. The greatest men on earth had moments of mental agitation which made them weep; and while listening with awe to the story of their affliction, we unconsciously reach for our handkerchiefs to dry our eyes. We are overcome by a certain feeling, which is another prerogative of the human race—sympathy. The power of weeping is frequently a great blessing; it calms and cools our over-heated brain, and may prevent even serious incidents. As the opening of a valve saves the boiler from explosion, so tears gradually melt away that rock which rests upon our breast, and threatens to smother us by its insupportable weight.

# CHAPTER XXV.

## Facial Expressions.

The eye is the mirror of the soul, the reflector of mental emotions. Words can be misconstrued, but not the language of the eye. The discourse of an orator has a powerful ally in the eloquent expression of his eyes; under their influence the listeners are spell-bound, their heart echoes every sentiment which flows from his lips: he is the charmer, his auditory the enchanted prey. The eye is also the gate through which we can fathom the bottom of the mind, it reveals its secrets better than a lengthy discourse will do. — But, how is it possible that this simple organ has such marvelous qualities, and by what means are they effected ? Of course, the eyeball by itself cannot produce these wonders, but in connection with its surroundings, the eyelids and the eyebrows, it is the magic wand which, as the story goes, enervates the approaching lion, and compels him to make a cowardly flight before the majesty of the unflinching human eye.* The answer to this question is, that the expression of the eye is due,

* The human eye has two distinctive peculiarities which we do not find in animals: the eyebrows and the prominently visible portion of the *white* sclerotic coat. This last characteristic feature of the human eye is perhaps the principal cause that every animal turns its eyes down or sidewise, as we can readily observe when we take hold of the head of our dog, and look at his eyes. Although he may be very fond of us, he nevertheless tries to avoid the fixation of our look; and after freeing himself, he will jump about for joy, lick our hands, crouch down and is highly delighted with his release from that unbearable enchantment of our stare. This accounts for the above story, because, if anybody is accidentally confronted by a lion, it is natural that he is stunned, motionless, or paralyzed, with eyes wide open, thus involuntarily showing that "ominous white" to greatest advantage, which no animal can face without shrinking from its magic spell. Lion-tamers make use of this weakness in all animals; they keep those beast under the stern influence of their eyes, and awe them into submission, in spite of their superior brutal strength.

1. To the changes of its surroundings, and
2. to the position of its axis of vision.

Of the part performed by the *eyelids*, that of the upper lid is the most important, because it is larger and more movable than the lower one. The raised, elevated lid admits free entrance of the full light, while the drooping lid shadows and darkens it.

The eyes are wide open when we listen to something of great interest, which causes either surprise or alarm. Half closed eyes indicate indifference and indolence, and produce a dull and drowsy look.

> "Were his eyes open? Yes, and his mouth too. —
> Surprise has this effect, to make one dumb;
> Yet leave the gate, which eloquence slips through,
> As wide as if a long speech were to come."

The *eyelashes* play also a great part in this respect. When they are long and fine, they impart to the eyeball a gentle and affectionate appearance, which the poets call "the sweet pensive shadow."

> "And eyes disclos'd what eyes alone can tell."

But when they are short and sparing, the look loses that mellowy appearance is rather unsympathetic, and gives the eye generally a cunning and sly air.

The *eyebrows* are powerful organs of expression; we can produce a frown by wrinkling and depressing the brows, while by elevating them we express incredulity, surprise, or contempt almost as plainly as by words.

> "Disdain and scorn ride sparkling in her eyes."

The *position* of the eye has another great effect; the so-called "deep eye," which is constantly shaded by the prominent forehead, makes a different impression from the "shallow" one. The deep eye is somewhat lacking the free motion of the upper lid, and as it is generally of a darker tint, besides being shaded by the projected forehead and eyebrow, it produces a determined, grave, often morose expression.

> "Yet well that eye could flash resentment's rays,
> Or, proudly scornful, check the boldest gaze:
> Chill burning passion with a calm disdain,
> And with one glance rekindle it again."

The shallow eye, mostly light colored, shows to perfection the innumerable variations of the human look. There is first the *staring look;* the eye is not fixed upon any distinct object, it is immovable and indicates hopelessness, pain, fright, terror. The "hopeless stare," after the loss of all energy, is characterized by an indolent silence; the drooping of the upper lid produces the appearance of a weary despondency.

"In those sad eyes the grief of years I trace,
And sorrow seems acquainted with that face."

In cases of violent excitement, the staring look is the result of the convulsive exertions of the outside muscles of the eyeball, which, by acting all at once, push the eye forward.

The look of the *over-joyful* is just the opposite; his eye is not staring in one direction, but is restlessly wandering from one object to another, because none is able to attract his attention long enough to counterbalance the inner excitement. By the quick changing of the position of his eyes, the observer receives constantly another reflection of them; such eyes *sparkle with joy.*

"The joy of youth and health her eyes displayed,
And ease of heart her every look conveyed"
" "While pleasure lights the joyful laughing eyes.""

The *color* of the eye is of little importance in the different expressions, but plays a prominent part at the time of courtship, when a lover goes into ecstasy over the color of the eyes of his beloved.

"Let other men bow, and utter the vow
Of devotion and love without end,
As the sparkling *black* eye in triumph draws nigh,
Its glances upon them to bend.
But give me the eye, thro' which I can spy
To the depth of a heart warm and true;
Whose color may vie with the hue of the sky; —
The soft, the sweet, love-beaming *blue!*"

All these changes of the eye are produced by the action of separate nerves. Some motions are controlled by our will, others are acted upon by the so-called sympathetic nerves which, for instance, regulate the dilatation and con-

traction of the pupil, and produce other phenomena beyond our control. But by means of an "iron will", or by long mental training, many expressions of the eye can be concealed from the observation of others. Skilled diplomatists, shrewd lawyers, professional swindlers, hypocrites and many more, often deceive others with sleek words and a trusting look; but the intelligent observer instinctively shrinks from their enticements, and is not easily caught by their deceitful schemes. The warning impression we receive as to the questionable truthfulness of their words is due to certain motions and positions of the eye, not controllable by their will. Their words do not touch the corresponding chord of our soul, they only cause dissonance and aversion of which we cannot give a clear account, but feel indistinctively.

"O what a tangled web we weave,
When first we practice to deceive."

There are persons who win our affection without any effort, although their exteriors are plain, their features irregular, their discourse lacking eloquence and depth of knowledge, and yet we are fascinated by them. This is the witchery of an *expressive eye*, the reflex of an honest, sincere mind.

"In one soft look what language lies!"

A close observer of the facial expressions of different individuals will find a great variety in their delineation, based principally upon the direction of the *axis of vision*. In children this axis is almost constantly parallel, producing the impression of thoughtlessness, or the childish innocent look. With increasing intelligence the eyes lose the parallelism by being fixed upon objects of investigation. All affections of the mind are now manifested by certain motions and positions of the eyes, which become more and more convergent. The lurking look of the convict on trial, the watchful scrutiny of the over-suspicious, the lustful look of the libertine, the piercing glance of anger, the rude gaze of the ruffian, and the fearful glare of the maniac; — all are modifications of the same act, produced by an increased convergency of the axis of the eyes.

The gentle and refined affections of the mind restore to a certain degree the parallelism of the axis. It is this which appeals in the eye of the trusting; sparkles in the eye of the happy and the gay; subdues in the eyes of the affectionate and the loving; awes and elevates in upward gaze of piety and religion; or composes in the gentle regard of the devout and resigned.

The eyes of a frightened person diverge; the wish to be far away from the place of danger causes the dilating of the pupils and the opening of the eyelids.

In old age the axis of vision again becomes parallel. The passions of former years are calmed, and the mind, in a contemplative mood, is now diverted upon its future distant home. At last the eye dies in the absolute parallelism of the axis of vision.

## CHAPTER XXVI.

### History of the Invention of Spectacles, and the Gradual Development of the Optical Trade.

(Old tradition credits Phœnician merchants with the invention of glass. This nation occupied a part of the coast of Syria, between the Lebanon and the Mediterranean Sea, northwest of Palestine, and was already widely known at the time of Jacob, the patriarch, about 1750 years before Christ. But it seems glass was known before that time, as there has been lately found below the ruins of old Nineveh a lens evidently used for optical purposes. A knowledge of the manufacture of glass was early acquired by the Egyptians, who improved on it, and made even colored specimens. After the Romans conquered Egypt, this art was introduced into Italy, where they soon learned to make plate-glass, and also produced a kind of glass which conld stand without injury the effect of hot fluids. They also claimed to have known a glass which was malleable, and to a certain degree unbreakable.) A good story in relation to this states that a man once demanded to be brought before the Emperor, to whom he presented a goblet of glass. The Emperor was highly pleased with the splendid workmanship of it, but when it passed from hand to hand among the courtiers present, it accidentally fell to the floor, or, as it is also related, the artist himself threw it wilfully down. It did not break, but was badly dented. The man repaired it immediately with a small hammer he had brought along with him. It is a pity that this important invention is entirely lost. One Roman historian reports that Nero could not see very well, and that he made use of a large jewel in the shape of a lens, to enjoy a better sight of the fights of his gladiators. But this was not imitated by others, and is narrated by the historian only as one

of the many strange extravagancies of this most remarkable man of the Roman empire.*

The history of the invention of spectacles is closely connected with the general advance of science, especially as regards *light*. Light was a familiar phenomenon to the ancients, and from the earliest times we find man's mind busy with the attempt to render some account of it. But without experiment, which belongs to a later stage of scientific development, little progress could be made in this direction. They satisfied themselves that light moved in straight lines; they knew also that these lines, or rays of light, were *reflected* from polished surfaces, and that the angle of incidence was equal to the angle of reflection. The first one who measured the *refraction* of glass and water at various angles, was Ptolemy, an Egyptian, about the year 150 P. C.; he states that the angle of refraction is always less than the angle of incidence.—Nine hundred years later, the Arabian mathematician, Alhazen, wrote a valuable book on the reflection and refraction of light, containing also a description of the eye, and a philosophy of vision. Although he gives directions for making experimental measures of refraction, he does not furnish any Table of the results of such experiments. Vitellio, a Pole, about 1250, wrote an extensive work on optics, including such Tables, and asserts them to be derived from his own observations, which is very doubtful.

We see that in the long period of eleven hundred

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* Nero was, perhaps, hypermetropic, but not myopic, as it is often stated. Myopia was not known in olden times, because it did not exist. Travellers have never found among uncivilized nations a case of myopia. People who do not read, or do not use their eyes for seeing small objects, are not near-sighted. In America, which is mostly an agricultural country, there are on an average twenty-five hypermetropics to one myopic (cities excepted), while in Germany, where printing was invented, there are twenty-five myopics to one hypermetropic person. Myopia is often hereditary, but decreases in a few generations when the cause for it is removed. It is simply a temporary abnormality, and is usually acquired as the result of certain habits; it is without doubt of modern date.

The causes of hypermetropia are not at all dependent upon the abuses of the eyes by reading or doing fine work. Many natural causes produce this abnormal condition, which is certainly as old as the human race, although it has been really understood and explained only in the present century. The close resemblance between myopic and hypermetropic eyes, compelling both of them to use spectacles for near and far, has wrongly caused many writers to make Nero near-sighted.

years little progress was made in science, because the human mind at that time took the opposite course of mental training. Instead of studying the forces of nature, and enjoying the bountiful gifts which an exceedingly friendly Providence had put within easy reach, people turned their eyes to the clouds till they lost sight of their beautiful surroundings. "The men of the Middle Ages were so occupied with the concerns of a future world that they looked with lofty scorn on all things pertaining to this one. Notwithstanding its demonstrated failure during so many years of trial, there are still men among us who think the riddle of the Universe is to be solved by their appeal to consciousness. And, like most people who support a delusion, they maintain theirs warmly, and show scant respect for those who dissent from their views." This is the reason why a man like Roger Bacon was hated and hounded to death, as happened to Galilei and other men of genius. — Bacon was a professor at Oxford, England; he made many wonderful discoveries in Optics as well as in Chemistry and Physics, which were regarded by his ignorant contemporaries, especially by the jealous members of his own religious order, as the work of the devil, and caused his imprisonment, at different times, for almost twenty years. He was the first to produce, or rather describe, a *convex lens*,* but we do not find in his works the least hint that he combined these lenses into spectacles.†

* A spectacle lens was discovered at Pompeii in 1854. This city was buried by an eruption of Vesuvius, in the year 79 P. C., and was again discovered in 1748.

† In his principal work, *Opus Majus*, he urges the necessity of a reform in the mode of philosophizing, and shows why knowledge had not made greater progress. It contains six parts:

I. On the four causes of human ignorance.
   1. Authority (the force of unworthy authorities).
   2. Custom (the traditionary habit).
   3. Popular opinion (the imperfection of the undisciplined senses).
   4. Pride of supposed knowledge (the disposition to conceal our ignorance and to make ostentatious show of our knowledge.

II. On the source of perfect wisdom in the sacred scripture.

III. On the usefulness of grammar (regarding correct translations).

VI. On the usefulness of mathematics.

V. On perspective.
   1. Organs of vision.
   2. Vision in straight lines.
   3. Vision reflected and refracted.
   4. Propagation of the impressions of light, heat, etc.

He died in 1294, and only a few years afterwards this was accomplished in Italy. (We may point to the year *thirteen hundred* as the one in which spectacles were invented, if we ignore the pretensions of the Chinese, who claim to have known them long before that time. However this may be, all inventions made by them were barren to the rest of mankind in consequence of their exclusiveness.

An old Latin document of the year 1303, found at the Convent of St. Catherine of Pisa, tells us that a monk, Alexander of Spina, who died in 1313, was so skillful a mechanic that he could reproduce any kind of work he had seen, or which had been described to him, and that he made spectacles after having seen them, and the inventor had refused to communicate the true process of their manufacture.* This selfish inventor was probably SALVINO ARMATO, on whose tombstone was the inscription:

Qui Giace
Salvino D'Armati Degli Armato
Di Firenze,
Inventore Degli Occhiali, MCCCXVII.

Here Rests
Salvino, etc., Armato
of Florence,
Inventor of Spectacles, 1317.

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The use of spectacles spread very slowly, because people had little need of them. Only a limited number of men could read, books were very scarce and very dear. Printing was not yet invented, all books were written by hand, and it was only afterwards, when their circulation increased, that spectacles came into demand. An old

VI. On experimental science.—

This sixth part is undoubtedly the most remarkable portion of his work. It is indeed an extraordinary circumstance to find a writer of the thirteenth century, not only recognizing experiment as one source of knowledge, but urging its claim as something far more important than men had yet been aware of.

* Ocularia ab aliquo primo facta, et communicare nolente, ipse fecit et communicavit.

chronicle of Nuremberg, in Germany, of the year 1482, mentions that there were several manufacturers of spectacles in that city.

Spectacles were for a long while merely objects of curiosity, and were made use of as a conspicuous novelty, as some years ago every "dude," male or female, had to wear *blue glasses* for fashion's sake. In Spain they formed a part of the costume of every well-bred person. This absurd use of glasses was meant to increase the gravity of the appearance, and consequently the veneration with which the wearer of them was regarded. The glasses were proportional in size to the rank of the wearer. Those worn by the Spanish nobles were sometimes three inches in diameter. The Marquis of Astorga, when having his bust sculptured in marble, particularly enjoined upon the artist not to forget his beautiful spectacles.

After this first silly introduction of spectacles, they again fell into disuse for nearly three hundred years, during which no improvements deserving notice were made. How different were the people of that time from the present generation! In less than no time we would have produced a *concave* lens also, and have presented the world with a spy-glass. Think how quickly some years ago the Telephone was followed by the Phonograph; the one transmitting speech, the other reproducing it. I have searched in vain to find the name of the inventor of the concave lens; it was not in use long before the invention of spy-glasses, I think.*

The credit for the invention of spy-glasses, or telescopes, has been claimed by the friends of three parties: John Lippershey, Zacharias Jansen, both of Holland, and Galilei, of Italy. There is no doubt that Galilei first applied the telescope for observing the stars; but he

* Mr. Child, an Englishman, has discovered lately in the Observatory at Pekin, China, an old astronomical telescope which was made in 1279, under the reign of Kublai Khan. Its mounting is cast in bronze, and is still well preserved. It was for four hundred years used as an ornament upon the terrace in front of the imperial palace, but was removed in 1670 to the Observatory by order of the emperor Khang. A photograph of this antique instrument has arrived a few years ago in London.

constructed his instrument after he had learned that by a combination of convex and concave lenses distant objects would appear much nearer. The real inventor of the telescope was without doubt John Lippershey, a spectacle maker at Middleburg, Holland. But according to Descartes, the inventor was Adrian Metius, who wrote on the 17th of October, 1608, to the government of Holland, stating that he, as well as the spectacle maker of Middleburg, was manufacturing the instrument "that brings distant objects near." Another document of Oct. 2d, 1608, lately found in the government archives, is the petition from Lippershey, praying for a thirty years' patent on his invention. This was refused him because the instrument could not be used with both eyes at once; and after he had made a double one, the patent was again refused, because telescopes were then being made everywhere. But as a partial compensation for his disappointment, he received an order to construct for the government two binocular instruments, the lenses of which should be of rock crystal, and for which he was to be paid 900 guilders, about $300 a piece.

The necessarily correct finish of lenses for telescopes gave a new impulse to the manufacture of spectacles, although they were still made in limited quantity by solitary workmen, and by hand. It is related of Spinoza, who died 1677, and who had learned the art of glass-grinding to make a living while writing his philosophical works, that he made a pair of spectacles for the celebrated German philosopher, Leibnitz, who had formed his acquaintance at The Hague, Holland.

The historical events which favored the development of this "New Era of Science" were:

The invention of printing, 1440;
the discovery of America, 1492; and
the gradual emancipation of the human mind from metaphysical dreams, 1517.

The astronomers took the lead in the march of progress, and the hitherto humble guild, or corporation of glass-grinders and manufacturers of spectacles, had to extend their former limited sphere to that of adroit mechanics. They not only built telescopes and other com-

plicated instruments used for scientific purposes, but also took personally an active part in the promotion of science by independent investigations and inventions.

The hero who made the first scientific application of the new discovery was Galilei, but his telescope was very nearly the same as the modern single opera glass, being composed of one bi-convex objective lens and one bi-concave ocular lens. The theoretical explanation of this telescope was given by Kepler, 1611, who also suggested the use of a *convex* ocular lens, which allows a larger field of vision, but shows objects inverted. An instrument of this order was constructed by the capuchin, Anton De Rheita, 1645, and is called the *astronomical telescope*; he afterwards added to the single ocular lens four separated convex lenses, thereby restoring the upright picture, and called it *terrestrial telescope*. This monk also constructed a binocular telescope which was regarded rather as a thing of curiosity than of practical utility, until in modern days his plan has been accepted in opera glasses, microscopes, etc. The great defect of these instruments was their chromatic aberration, and to overcome this, enormously long telescopes were made. Huyghens, for instance, used an instrument of his own make, with an object lens of 123 ft. in focal length; which is still in the library of the Royal Society of London. It incited the ambition of others to construct even longer telescopes; as Divini at Rome, Campuni at Bologna, and Auzout at Paris. It is stated that the latter made telescopes of from 300 to 600 feet focus, but they never could be used in practical observations. In these very long telescopes no tube was employed, and they were consequently termed *aerial telescopes*. Huyghens finally constructed one of 210 ft. long, but such instruments were unmanageable and soon went out of use. Besides, the increase of the aperture of object glasses could not altogether remove the coloration of the image produced.

Newton, who discovered the principle of the chromatic defect in lenses, maintained that the evil was irremediable, and that any combination of lenses could no more refract without producing color, than a single lens; he,

therefore, constructed, 1671, a *reflecting telescope*. He is not the inventor of the reflector, as James Gregory is credited with its invention, but on account of Newton's effort in its favor, it rapidly came into general use in England, being called the "Newtonian reflector," in opposition to the "Gregorian," manufactured afterwards by James Short and others. In 1718, Hadley made a mirror, six inches in diameter, with a focal length of 62 inches and a magnifying power of 230 diameters. In 1789, the elder Herschel constructed a reflector of forty-five feet length, with a speculum of four feet in diameter, with which he made wonderful discoveries.

About the year 1747, Euler doubted the exactness of Newton's proposition, and he declared that a combination of lenses of *different media* would give a colorless image. The Swedish mathematician, Klingenstierna, confirmed the correctness of Euler's suggestion by calculation, and in 1757, John Dollond demonstrated it by inventing the *achromatic lens*. It is said that Chester More Hall, was led by the study of the human eye, which he conceived to be achromatic, to construct an achromatic telescope as early as 1729, but kept his invention a secret. John Dollond and his son, Peter, constructed achromatic telescopes of three feet, which produced an effect as great as those on the reflecting principle forty-five feet long. Ramsden introduced, 1783, an eyepiece of two plano-convex lenses of equal focus, with their convex surfaces towards each other, and separated by a distance of two-thirds of their common focal length. By this arrangement, a *flat field* is gained, and the chromatic and spherical aberrations are so much reduced as to be practicably imperceptible.

The hope, now to construct instruments of unlimited size, was frustrated by the impossibility of obtaining large pieces of flint glass, and there was no material improvement in this direction for several years, till Fraunhofer, with the assistance of François Guinand, gave a new impulse to this branch of the optical business. Joseph Fraunhofer was born 1787, at Straubing, Bavaria; he was the son of a poor glazier, and was in his earlier years employed at the same trade. After his father's

death, 1799, he entered as an apprentice the establishment of a mirror-maker at Munich, where he had, 1801, the singular misfortune of being buried alive by the collapse of his boarding house. His miraculous rescue attracted the attention of the king, who made him a present of 18 ducats (about $40.00), for which he bought a machine to grind spectacle lenses. In 1806, he accepted the position as foreman in Utzschneider's optical establishment, where he soon became the greatest optician in Germany. His excellent telescopes and microscopes are known throughout Europe. Fraunhofer will always take a prominent place in the history of the optical trade; he was not only a practical and most skillful workman, but also a scientist of great renown. Still, a shadow darkens his fame, *his selfish exclusiveness*, which restrained him from making known, for the benefit of science, the true process of the manufacture of his perfected flint glass in large pieces. It was hoped that after his death some clue would be found among his writings; but, strange to say, his secret went with him into the grave.—His time can be considered as the beginning of the latest era in the development of the optical trade. The instruments for astronomical observation became an object of serious care. Extensive knowledge, intense thought, and great ingenuity were requisite in the astronomical instrument-maker. Instead of ranking with artisans, he became a man of science, sharing the honor and dignity of the astronomer himself.

We now turn our attention from the telescope to its powerful rival, the *microscope*. The telescope had rudely dispelled our self-conceited error, that the earth is the pivot on which the whole Universe revolves, by revealing myriads of new worlds, thus forcibly teaching the mortifying lesson of our own insignificance. The microscope, acting as an antidote to the former, again restored our smallness to a state of gigantic greatness; it revealed a world of hitherto invisible wonders of nature, and clearly manifested that everything, great or small, is equally marvelous. These two instruments have done more for the enlightenment of men than any invention

before or since. The invention of the *simple microscope* is not claimed by any one; we do not know the inventor. The earliest magnifying lens known, if indeed it was used for this purpose, is the rude one found by the Englishman, Layard, in the palace of Nimrud (at Nineveh); it is made of rock crystal, and is far from being perfect. Aristophanes tells us that *burning spheres* were sold in the shops at Athens, about 400 years B. C. There is no evidence that lenses were used at this early date for magnifying purposes, but, instead of them, glass globes filled with water, which Seneca alludes to, were employed.

It is not until the seventeenth century that we find powerful magnifiers of glass, actually employed for scientific investigation. Most of the magnifiers used by the early observers were minute single lenses of glass, often small spheres formed by melting threads of glass. The small single lenses of high power are usually plano-convex, the plane side toward the object. Upon David Brewster's suggestion, lenses were ground by Peter Hill, a skillful optician of Edinburgh, and by Pritchard, of London, of garnet, sapphire and diamond.*

The garnet lens was found superior to all others, being free from double refraction, and even superior to glass. Brewster also invented a very powerful single microscope, known as the *Coddington Lens*, which consists of a sphere with a deep concave groove cut around it, and

* Some years ago two opticians of Paris, Trecourt and Oberhauser, laid before the Parisian Academy lenses of the diamond, sapphire and ruby, which were used in connection with glass lenses in microscopes, but they had no advantage over glass. A letter from David Brewster, lately published, explains the cause of the failure. He says of his own experiment, above mentioned: "The diamond, before it was worked, had all the appearance of internal brilliancy; but, after being polished, it presented a series of stratified shades, which rendered it useless for the required purpose. I afterwards learned that lapidaries were acquainted with this appearance, and were unwilling to take the risk on themselves of cutting up diamonds for optical purposes. On a minute examination of this phenomenon, it appeared that these different shades occurred in regular strata, each section being about the one-hundredth part of an inch, and each stratum having a different focus, and being of a different degree of hardness and specific gravity. The inferences drawn from the above facts were: that the diamond was a vegetable substance, and that its parts must have been held in solution and subjected to different degrees of pressure at the different stages of existence. If, on the contrary, it was of mineral origin, as is generally believed, it would be subject to the laws of crystallization, and its crystals would necessarily be homogeneous and not stratified.

blackened so as to shut off the marginal pencils of light, thus giving a wider field and a more perfect image of the object. In the *Stanhope Lens*, the curvatures are unequal, but its magnifying power is so strong that a drop of water may be examined by applying it to the less convex, or plane surface.

In the construction and use of lenses two great difficulties present themselves. It is practically almost impossible to make small lenses with any other than spherical curves, and unfortunately simple spherical lenses do not bring the rays to a perfect and exact focus. If it were possible to construct lenses with elliptical or hyperbolic curves, the spherical aberration would be avoided; but even then, since the different rays of the spectrum are refracted differently, the focal length for red light would be greater than for blue, and it would be impossible to obtain a sharp image free from chromatic aberration. In order to overcome these difficulties, *doublet* and *triplet* lenses were invented and introduced, which led gradually to still greater combinations, till the simple microscope was transformed into a *compound* one, now the only instrument used for minute researches. The theoretical and practical difficulties that had to be overcome in developing the best modern compound microscope from its embryonic condition were so great that, until within the last seventy-five years, the very possibility of success was doubted by the highest authorities in optical science.

The manufacture of microscopes was much favored in England. Since the time of Ramsden, there has been an industrious contest among the English opticians in perfecting that instrument more and more, and they were greatly encouraged by the liberal support of the English people. There is hardly a college or school without it, many ships carry a good instrument, even private studios and parlors are supplied with the luxury of an improved microscope. Among the many skillful opticians I may mention: Wenham, Swift, Parkes & Son, Stephenson, Smith & Beck Bros., Powell & Lealand. — Other nations were not so liberal in their support; for instance, the French opticians were chiefly dependent on the export of their instruments, and although they did not keep step

with the English manufacture, still some opticians made quite a reputation for themselves; as Chevalier, Nachet, Oberhauser, Hartnack, etc. Since the time of Fraunhofer, the German and Italian opticians also produced fine instruments which could be favorably compared with the best English microscopes. There was Amici at Modena, G. & S. Merz at Munich, S. Ploessl at Vienna, C. Zeiss at Jena, and others of great ability. — America was for many years a profitable market for European instruments, but since Chas. A Spencer, Robert B. Tolles and others, we can fully compete with the old world as regards telescopes and microscopes. Only in the manufacture of Opera Glasses we are still in our infancy, although the demand for them is such that they form an important article of manufacture, of which Paris is the great seat. So largely and cheaply are they produced in Paris, that it has nearly a monopoly of the trade. They can be bought from 75 cents up to $30.00 a piece. The cheapest opera glasses consist of single lenses; those of the better class have *one* compound achromatic lens. A very ordinary construction for a medium price is to have an *achromatic* object-lens, and a *single* eye-lens. In the finest class of opera glasses, both the eye-lenses and object-lenses are achromatic. Ploessl's celebrated field-glasses (Feldstecher) have twelve lenses, each object-lens and eye-lens being composed of three separate lenses.

Almost every inventor and scientific discoverer has laid claim on our dexterity to execute his idea; Wollaston came with his Camera Lucida, Wheatstone with his Stereoscope, Daguerre with his Photographic Camera, Faraday with his Electric Machines, Morse with his Telegraphic appliances, Kirchhoff and Bunsen with their Spectroscope, the Sugar-Industry with its Polariscope, Helmholtz with his Ophthalmoscope and the Oculists with their Compound Lenses. Indeed, we have to make instruments for Electricians, Surveyors, Navigators, Astronomers, Chemists, Physicists, Meteorologists, etc.; but it is only within the last century that our trade has risen to that great prominence it occupies to-day. We are now an indispensable factor in scientific pursuits, and furnish instruments, not only the most scientific,

but also the most useful ever offered to benefit the world. We have reason to be proud of our achievement, but we must not forget that we were merely the tools, executing the order of scientists, who did the brain work for us and that we have not many opticians like *Fraunhofer* and *Chas. A. Spencer* to boast of.

The spectacle business advanced considerably after the oculists detected the asymmetrical refraction of the cornea, called *Astigmatism*. Thos. Young, of England, made the first studies in astigmatism in 1783, but it was little noticed by his contemporaries. It was only after Donders, Helmholtz, Graefe, Javal, Knapp, and others, more than fifty years afterwards investigated it, and explained the method of its correction by means of *cylindrical lenses*, that it was generally understood. The manufacture of such cyl. lenses with all their combinations, and especially their *correct setting*, was a new departure in our trade, and many opticians were considerably troubled before they fully mastered the difficulties in connection with this most delicate correcting medium in the shape of spectacles. A competent optician of 1860, falling asleep like *Rip Van Winkle*, and awaking to-day, could not fill the simplest order of an oculist, but would have to learn his trade over again.

As long as the selection of spectacles was left to the opticians, they contented themselves with the correction of a limited number of defects, and declared the remainder incurable. They did not know the nature of irregularities, such as Hypermetropia or Astigmatism, and were, therefore, totally in the dark about their correction. Oculists formerly considered it beneath their dignity to concern themselves with spectacles, and after they had restored the injured or suffering eye to a healthy state, they turned the patient over to an optician for the proper selection of glasses, unconcerned whether his selection was a good or bad one. It is only since prominent oculists investigated such "incurable" cases, that they can be thoroughly corrected by spectacles. Although they are manufactured by opticians, the credit of their beneficial action belongs to those eminent explorers who gradually wrenched their selection from the

hands of mostly indifferent mechanics, who, destitute of the necessary scientific education, have to content themselves at present with a secondary position under the leadership of the oculists. There is no blame attached to our present position, as it is not at all a step backward. On the contrary, the standard of our trade has advanced considerably, but it has not kept step with the gigantic progress of Ophthalmology, which has no equal in medical history. In the last thirty years Ophthalmology and general Surgery have become exact sciences, while the rest of medicine is yet for the most part empirical, as was the case with our mechanical and hap-hazard manner of selecting spectacles, when the patient was the principal judge of their correctness.

The selection of spectacles in complicated cases is now extensively practiced by oculists, who are, as physicians, qualified to *prepare the eye* for a thorough examination. Any optician, tampering with the eyes of an easily frightened customer, may cause himself great trouble if he cannot legally attach to his name an M. D. Only cases of simple presbyopia, manifest myopia, hypermetropia, and some cases of astigmatism, may be properly investigated by an optician, because the other and more complicated errors of refraction require that the ciliary muscle be temporarily paralyzed by a mydriatic, and that in this state of the eye accurate and repeated measurements be made with test-types and trial lenses. Signs in the windows of opticians which read: "Examination of the eyes made free of charge," smack of quackery, and should be removed.

If I now allude, briefly, to the part America has taken in the general development of the optical trade, I have to draw the attention of the reader to the well known fact that we had during the colonial time no industry worth mentioning; we simply exchanged our natural and agricultural products for English manufactures. Optical goods were still imported from Europe long after the establishment of our political independency from England. —The first one mentioned in this respect is Godfrey, who was, after all, no optician but a glazier; he invented the sextant. He was of Philadelphia, (for many years

the headquarters of our slowly developing optical industry); so was Rittenhouse, McAllister, Queen, Saxton, Zentmayer, etc. Other states soon followed in the path Pennsylvania had so ably opened; especially New York, with a fair line of opticians and inventors, like Fitz, Wales, Grunow, Spencer, Draper, Prentice, Fassolt, etc. Massachusetts was conspicuously represented by Tolles and Alvan Clark; even a Southern state by Riddell. At present nearly every Northern, Middle and Western state can boast of some competent opticians. Since the last fifteen years we manufacture all frames for spectacles and eyeglasses, and also have commenced lately to grind our own lenses; I mention in this respect, Bausch & Lomb in Rochester, the American Optical Co. in Southbridge, and the Katonah Optical Co.

In concluding this chapter, we must bear in mind that when we come to a great man who discovers or lays down new laws, there have always been a number of less known observers who have collected the facts from which he has formed his conclusions. Every country contributes its share to the development of science; we may, therefore, say that science is international. Its achievements are open to the world at large, and the readiness with which any nation accepts and introduces them shows its average intelligence. A superficial comparison of the most prominent discoveries contributes greatly to discriminate between the special characters of the different nations. *France*, for instance, excels in inventions for enjoying and beautifying life, thereby showing the happy disposition to take life mostly from the rosy side; *German inventions* bear a more scientific, yea serious aspect, indicating a rigorous submission to life's sobriety; *England*, the favorite foster-child of the world, prances proudly in the general race of progress, but with a significant wink to realistic ends; and—America follows her example. It individualizes each step of progress by the distinction of a patent, which is by no means an impediment to progress, but, on the contrary, a fruitful cause of many important inventions. America is the foremost advocate of this doctrine, and is benefited by it to such an extent that at present our telescopes, microscopes,

and above all, our *spectacles* can stand a fair comparison with the best European manufacture. Fifty years ago, we still imported all optical instruments and appliances from England, France or Germany; but of late we only import the *optical glass*, and do to a good extent the grinding of lenses here as well, or even better, than they formerly did in Europe. If our glass-industry had advanced in the same proportion as the other branches of the optical trade, we also could expect in the near future an emancipation from the further importation of that article.

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### Different Names for Spectacles.

The English word *Spectacles* is the plural form of spectacle, which is derived from the Latin noun *Spectaculum*, a sight, a show, and is formed from the verb *spectare*, to look at; to behold.

The French word *Lunettes* is also the plural of lunette, which means a little moon, a "moonlet," referring to the round shape of spectacle lenses.

The German word *Brille*, like the Dutch *Bril*, and the Danish *Briller*, is derived from Beryl, a transparent green-bluish mineral, called by the jewelers Aqua Marine. In former years people in Germany called all colored glass Berylle, and as a great many spectacles, especially those worn for fashion's sake, were set with plain colored glasses, this optical instrument received its name from that mineral. The Latin name for it is *berillus*, the fundamental idea of which denotes a shining or sparkling mineral substance, a crystal or crystal-like glass. The noun *brilliant*, now used only in reference to diamonds, is derived through the medium of the French word *briller*, to shine, to glitter, to sparkle (present participle, *brillant*).

Italians say *Occhiali;* occhio = eye.
Spaniards say *Ante ojos;* ante = before, ojo = eye.
Portuguese say *Oculos*, eyes.
Modern Greeks say *Dioptres.*
Poles say *Okulary.*

Swedes say *Glas-ögen*, glass-eyes.
Russians " *Ozku* (atschküi); Otsko = eye.
Roumanians say *Ochilary* (ot-chee-la-re).
Hungarians " *Papaszem.*
Turks say *Guzlegún.*
Hindoos say *Chasma* (tchasma), frame.
Hebrews " *Sechuchis l'Ayin.*
Chinese " *Nong-Kieng*, eye-glass.
Japanese " *Megáne*, eye-mirror; and in
Volapük, we say *Lün.*

# CHAPTER XXVII.

## Prominent Opticians, Scientists and Inventors.

> "It is the commendation of a good huntsman to find game in a wide wood, but it is no imputation if he has not caught all." Plato.

*Airy*, Geo. B., born 1801, an English astronomer, first at Cambridge (1828), and since 1835, at the Greenwich Observatory. He has deservedly the reputation of being one of the most able and indefatigable of living scientists. His important contributions to astronomy, magnetism, meteorology, and other sciences are contained in leading cyclopædias and in the annals of learned societies. He introduced several new astronomical instruments, among them the water-telescope, the transit-circle, and the large equatorial erected from his plans in 1859. He published, 1851, "Six Lectures on Astronomy"; in 1866, "The Undulatory Theory of Optics; in 1869, "On Atmospheric Chromatic Dispersion," etc. He made many researches in physics and optics, and is the inventor of cylindrical lenses for the correction of astigmatism.

*Alhazen*, Abu Ali (died 1038 at Cairo, Egypt), was a great mathematician, and the first notable discoverer in optics after the time of Ptolemy. To him is due the explanation of the apparent increase of heavenly bodies near the horizon; he also taught that vision does not result from the emission of rays from the eye, which was the favorite theory for many centuries before and after him. He wrote a book on the refraction of light, especially on atmospheric refraction, showing the cause of morning and evening twilight. Only two of his works have been printed, his "Treatise on Twilight," and his "Thesaurus Opticæ," or collection of optical facts.

*Amici*, G. B. (1784-1863), a celebrated optician and astronomer at Modena, Italy; constructed the best reflectors and greatly improved achromatic microscopes. He invented and perfected also different kinds of camera-lucida for drawing purposes.

*Arago*, D. F. (1786-1853), celebrated French physicist; discovered the colored rings of crystallized plates in polarized light. Upon this discovery is based the principle of the "polarizer" for testing pebbles.

*Archimedes* (287-212 B. C.), the most celebrated ancient mathematician; invented the hollow "Archimedes' Screw," a machine for raising water. He discovered the problem that a solid body, immersed in water, loses so much of its weight as the water would weigh which is removed by the body (specific gravity). In defending his native city, Syracuse (Sicily), against the Roman fleet under the command of Marcellus, he is said to have made use of powerful burning mirrors.

*Argand*, A. (1750-1803), a Swiss chemist; invented, 1782 a lamp called after himself. The wick has the form of a hollow cylinder, through which a current of air ascends, so that the supply of oxygen is increased. This contrivance prevented the waste of carbon, which in the old lamps escaped in the form of smoke, and it greatly increased the amount of light. He also added the glass-chimney, by which a draft is created and the flame rendered more steady.

*Bacon*, Roger (1214-94), studied at Oxford and Paris, where he received the degree of Doctor of Theology. After his return to England, he accepted a professorship in the University of Oxford. Here he joined the brotherhood of the Franciscans, and was termed by his brother monks "Doctor Mirabilis." His science and philosophy was almost universal, embracing Mathematics, Mechanics, Optics, Astronomy, etc. He made many discoveries, or had some knowledge of the most remarkable inventions which were made known soon

afterwards. His principal work "Opus Majus," was addressed to Pope Clement IV (1265-68), who was formerly Legate to England, and who admired the talents of the learned monk, and pitied him for the persecution to which he was exposed.—The influence of Bacon upon his contemporaries was not great; he was suspected of magic and was placed several times in close confinement in consequence of this charge, once for ten consecutive years (1268-78).

*Barlow*, Edward (1639-1719), an English mechanician, invented, 1676, the repeating clock and watch.

*Baumé*, Antoine (1728-1804), a French chemist. His areometer, also called according to its applications hydrometer, saccharometer, etc., made him widely known. It is still in use for measuring the specific gravity or density of different liquids heavier or lighter than water.

*Biot*, J. B. (1774-1862), celebrated French mathematician and physicist; studied with success the discovery of Arago, and published some important researches about polarization and double refraction. He still defended Newton's emission theory of light.

*Boulton*, Matthew (1728-1809), a skillful English machinist; inherited from his father an extensive steel manufactory, which he changed into a manufactory of steam engines, after he had associated himself with the penniless optician, James Watt. The improvements of steam engines were the joint efforts of both, although they are now chiefly credited to the genius of the latter.

*Bradley*, James (1692-1762), an eminent English astronomer, was 1721 appointed professor of astronomy at Oxford. In 1727, he announced the important discovery of the aberration of light, which serves to demonstrate the earth's motion around the sun. In 1741, he became the successor of Halley at the Observatory of Greenwich. His greatest discovery was in 1747; he found that the relation of the earth's axis to the ecliptic is not constant, a fact which explained the precession of the equinoxes and the nutation of the earth's axis. This discovery forms an important epoch in astronomy.

*Bramah*, Jos. ( 1740-1814 ), an English mechanic ; invented the "hydraulic press" (1795).

*Brandt*, Geo. ( 1694-1768 ), a Swedish chemist and mineralogist; discovered, 1733, the metal Cobalt, now so extensively used in the manufacture of blue lenses.

*Breguet*, A. L. (1747-1825), celebrated French mechanic, made many important inventions in watchmaking as well as in physics. He invented the metal thermometer which consists of a thin strip of metal, composed of three layers, of silver, gold and platinum. This strip is curled up into a helix, the silver being outermost. As the temperature rises the silver expands more than the gold and the gold more than the platinum, and the helix coils itself up; in lower temperature it acts the opposite. The end of the helix carries an index by which its rotation is made manifest.

*Breisig*, professor at Danzig, Prussia, invented the panorama. The first public exhibition was made, 1787, in Edinburgh, by Robert Parker.

*Brewster*, Sir David (1781-1868), celebrated English physicist; made great discoveries in the polarization of light and in double refraction of crystals; invented the "kaleidoscope," and described the Coddington lens. In 1832, he published his "Treatise on Optics," wrote many valuable articles for the "Encyclopædia Britannica," and was one of the last defenders of the "emission theory." He is called the "Father of Modern Experimental Optics."

*Bunsen*, R. W., was born 1811, professor of chemistry in Germany; invented a burner which bears his name. In 1860 he invented the magnesium light which has proved so important in photography. The greatest discovery with which his name is associated, is that of the "spectrum analysis," made in conjunction with his friend, Kirchoff, which has been the means of working so many wonders in chemistry, and revealing so much to astronomers.

*Celsius*, A. C., (1701-44), a noted Swedish astronomer; divided the scale of the thermometer into one hundred equal parts, from the freezing point of water to its boiling point, in opposition to Reaumur and Fahrenheit.

*Chevalier*, Arthur, born 1830; inherited, 1859, the large optical establishment at Paris from his father, Charles Chevalier. He, as well as his father, has made many improvements in the appliances for microscopes and other optical instruments. He published several instructive books; "The Art of an Optician," "The Student of the Microscope," "The Student of Photography," "Handbook of the Oculist Student," (Manuel de l'Etudiant Oculiste), etc.

*Clark*, Alvan, (1804-87), of Cambridgeport, near Boston, is the most eminent manufacturer of telescopic lenses. He is a self-made optician, had never seen a lens ground; was formerly an engraver and portrait painter, but began, 1844, to study technical optics and astronomy in order to assist his oldest son, George B. Clark, a student at Andover, in his studies as engineer. Both, father and son, experimented in making a reflecting telescope, and succeeded so well that they continued, and gradually established a reputation here and in England. After his second son, Alvan G. Clark, a practical machinist, joined the establishment, they tried to construct "refractors," and increased their lenses to sizes unknown before. In 1860, they constructed a telescope with a lens of eighteen inch diameter, and sold it to the Astronomical Society of Chicago. Up to that time, fifteen inches had been the diameter of the largest lens in the world.—During the war they were kept busy making binocular field glasses for the army, but soon resumed the manufacture of telescopes. In 1871, they constructed a telescope for the Naval Observatory at Washington, with an objective lens of twenty-six inches in diameter; they also made a duplicate of it for the Lee University of Virginia. The next great telescope was made for the Russian Observatory at Pulkowa; it has a clear aperture of thirty inches, a focal distance of 45 feet, and a

magnifying power of 2000 diameters. But the greatest triumph of their technical skill is the new telescope of thirty-six-inch diameter for the Lick Observatory of the University of California. — He made several discoveries; he invented a double eyepiece, and devised a very accurate method of measuring small celestial arcs.

*Coddington*, Henry (died 1845), an English mathematician; published, 1829, a valuable book in two parts "System of Optics." In 1830, he published an essay "On the Improvements of Microscopes," in which he strongly recommended the "grooved sphere" lens (first described by Brewster in 1820), which by his recommendation was brought into general use under the name of "Coddington Lens."

*Cooke*, Thomas (1807-68), of York, England; was originally a shoemaker in a small country village, but at the age of seventeen opened a school and in his leisure taught himself geometry and mathematics. His ambition was to construct a reflecting telescope, which led him to grind and polish lenses and specula, and with great perseverance and rare skill he accomplished his purpose. He then studied the optical laws of refraction in order to make an achromatic refractor; he constructed one of four inches, which had an admirable defining power. This telescope established his name as an optician; he gave up teaching and took to telescope-making. He opened, 1836, a shop in York, added to it the business of a general optician, his wife attending to the sale in store, while he was working in the back-room on telescopes. With the assistance of his brother as grinder, and his sons as mechanics, he erected in 1855 a complete factory. His work was always first-rate, and became known all over the world. In the same year, at the first Paris Exposition, his six-inch equatorial telescope was awarded the highest prize, a silver medal. — He turned out many telescopes, but the largest had only an aperture of ten inches, while Merz & Mähler, of Munich, made some of fifteen inches, and Alvan Clark, 1860, one of eighteen inches. Cooke was too ambitious not

to try to beat them; he, therefore, commenced to make one of twenty-five inches, but before it was mounted, his health broke down, he died from mental anxiety and over-work. Many call him the "English Fraunhofer."

*Copernicus*, Nic. (1473-1543), was the founder of modern astronomy; demonstrated that the sun was the center of our system. Up to his time it was taken for granted that the earth was the center of the Universe, and that the sun with the planets, and all the stars were moving around it. His theory was received with the same opposition as, one hundred years later, Huyghen's undulatory theory of light. The strongest opponent was the astronomer Tycho Brahe, and the Church, which persecuted all prominent defenders of this theory. (See Galilei.)

*Cronstedt*, A. F. (1722-65), a Swedish mineralogist; discovered, 1751, the metal Nickel.

*Daguerre*, L. J. M. (1789-1851), a French painter, known as the inventor of the present photography. His pictures were called "Daguerreotypes," after his name, and were first exhibited at the Paris Academy by Arago, 1839. This invention compelled the optical trade to manufacture the Camera Obscura.

*Dalton*, John (1766-1844), celebrated English physicist, and founder of the atomic theory of chemistry. He was the first who published facts about color-blindness, called foolishly after him "Daltonism."

*Descartes*, René (1596-1650), known also by the Latin name "Cartesius"; was the most remarkable philosopher and greatest mathematician of his age. His "Dioptrique," published in 1639, is an everlasting monument to his talent and acuteness of mind. He demonstrated that the aberration of a spherical lens would be considerably diminished by increasing the convexity of its axis, viz. by changing the spherical curve into a parabola. He also proved (1637) that the image formed upon the retina is inverted. He is the father of modern philosophy, and the founder of analytic geometry.

*Dollond*, John (1706-61), an English optician, well versed in mathematics; was a silk-weaver in his youth, and employed his leisure hours in the study of science. He invented the achromatic telescope, for which he received the Copley medal from the Royal Society of London (1758).

*Dollond*, Peter (1731-1820), improved upon his father's efforts, in conjunction with his brother-in-law, Ramsden. He published an "Account of the discovery of refracting telescopes" (London, 1789).

*Donders*, F. C. (1818-89), a Dutch physician, studied at the University of Utrecht; practiced first at The Hague, then established at Utrecht an institution for treating diseases of the eye. His principal works are: "Study of the Movements of the Eye," 1847; "Astigmatism," 1862; "Anomalies of Accommodation and Refraction of the Eye," 1865. His researches regarding Hypermetropia and Astigmatism created a new epoch in Ophthalmology, and although he was ably assisted by independent discoveries, in this line, by different co-laborers, his name will forever brightly shine in the annals of optical science as a benefactor to mankind, and as an original scientific investigator.

*Drummond*, Thomas (1797-1840), a Scottish engineer; invented, 1825, the "Drummond Light," also called "lime or calcium light."

*Euler*, Leonard (1707-83), an eminent Swiss mathematician. In 1733, he accepted the professorship of mathematics at St. Petersburg; in 1741, Frederick the Great, appointed him professor of natural sciences in the newly erected Academy of Sciences at Berlin; in 1766, he returned to St. Petersburg, where he remained to the end of his life. The last fifteen years of his active life he was blind, but that did not prevent him from still publishing several important works. His valuable "Treatise on Dioptrics" (Dioptrica), in three volumes (1769-71), was dictated by him when blind.

He was a great admirer of Newton, whose marvelous achievements he investigated most critically; this led him sometimes to correct Newton, as we see in regard to achromatism.

*Fahrenheit*, G. D. (1686-1736). He was the first who used mercury in thermometers (1714), instead of colored alcohol. He determined the zero-point by mixing salt with chopped ice, contrary to Reaumur, who put the zero at the freezing-point of water. He also invented the first practical areometer, to measure the specific gravity in fluids, and the first thermo-barometer.

*Faraday*, Michael, ( 1791-1867), one of the most distinguished chemists and natural philosophers of the present century. He was born near London, and was early apprenticed to a bookbinder; he devoted his leisure time to reading books and making experiments with an electric machine of his own construction. Humphrey Davy, professor of chemistry at the Royal Institute, engaged him (1812) as his assistant, and here he first showed some of that extraordinary power and fertility which have rendered his name familiar to everyone acquainted with physics. In 1827, he was appointed a regular professor of chemistry. His greatest work published is the series of " Experimental Researches in Electricity," which comprise all the investigations and discoveries made by him during the last forty years of his active life. From 1825-29, in conjunction with Sir John Herschel, he tried to improve the manufacture of glass for optical purposes. Practically considered, this investigation was a failure, but the "heavy glass" they produced led afterward to two of his greatest discoveries: the " magnetization of light," and the "diamagnetism."

*Fasoldt*, Charles, (1814-89), of Albany, N.Y., was a chronometer-maker by profession, but devoted himself in his later years to optical science. He was a mechanic of marvelous ingenuity and wonderful exactness and skill; his greatest invention is a machine for micrometric rulings, of a peculiar construction. His latest rulings

were so fine that the strongest microscopes could not resolve them, till he invented the "vertical illuminator", by which some expert microscopists succeeded in the resolution of 230,000 lines to an inch; but his machine is capable of ruling one million lines to an inch. His rulings are the best test to determine the strength of microscopes.

*Fitz*, Henry, ( 1808-63), a skillful telescope-maker; was a printer, but afterwards learned the trade of locksmith. In 1835, he made his first telescope, and in 1845, he exhibited an instrument that brought him into favorable notice of eminent astronomers. He made telescopes for the University of Ann Arbor, Mich., for the Washington University of St. Louis, for the Dudley University at Albany, etc. His largest telescope had an aperture of thirteen inches. He was an optician entirely by his own tuition.

*Franklin*, Benjamin, (1706-90), an illustrious American statesman, and one of the founders of our Republic; invented the lightning-rod, and the bi-focal spectacles, which were named after him.

*Fraunhofer*, Joseph, ( 1787-1826), the greatest German optician, instructed himself in lens grinding, was employed, 1806, as a working optician in the establishment of Reichenbach & Utzschneider. While there, he acquired considerable wealth through his inventions, and became sole proprietor of the establishment in 1819. One of his first inventions was a machine for grinding and polishing mathematically uniform spherical and parabolic surfaces; he also was the first who succeeded in polishing lenses and mirrors without altering their curvature. He invented a new heliometer and a circular stage-micrometer for microscopes; his improved crown and flint glass superior to any English, enabled him to manufacture his renowned achromatic microscopes and telescopes. But that which rendered his name celebrated throughout the scientific world is his discovery of the lines in the solar spectrum ( 1815), called Fraunhofer's

lines, which were first noticed by Wollaston in 1802, but F. published an illustrated map of fully 570 of them, assisted in his discovery by large prisms he had made of his clear flint glass. His tombstone bears this inscription: *Approximavit sidera*, (he drew the stars nearer).

*Fresnel*, A. J., (1788-1827), celebrated French physicist and inventor. His researches on the aberration, diffraction and polarization of light, completely overthrew Newton's Emission Theory, and proved the correctness of Thomas Young's defense of the Undulatory Theory of Light. His work on the "diffraction of light" was crowned by the Academy of Sciences in 1819. He also considerably improved the system of illumination for lighthouses.

*Galezowsky*, Xavier, born 1833, in Poland, studied medicine at St. Petersburg; went to Paris in 1858, became the assistant of the celebrated oculist Desmarres, and subsequently erected a clinic for eye-patients. He invented the trial-frame with the half circle attached, divided into degrees, for the determination of the faulty meridian in astigmatic eyes.

*Galilei*, Galileo, (1564-1642), the creator of experimental science, was born at Pisa, Italy; studied first medicine and philosophy, then mathematics. He utilized the pendulum in the construction of a clock for astronomical purposes, and invented a hydrostatic balance by which the specific gravity of solid bodies might be ascertained with the nicest accuracy. He also discovered the laws of motion, i. e. that all falling bodies of the same specific gravity, great or small, descend with equal velocity. Among other discoveries may be noticed a certain species of thermometer, a proportional compass or sector, also the construction of a refracting telescope for astronomical investigations and of a microscope. By means of his telescope he commenced his astronomical researches; he found that the moon was not self-luminous, but owed her illumination to reflection, and pronounced the milky way a track of countless sep-

arate stars. In 1610, he discovered the four satellites of Jupiter; he also was the first to note movable spots on the disk of the sun, from which he inferred the rotation of that orb. He soon openly advocated the Copernican system, and was in consequence denounced as a propounder of heretical views, and summoned to appear before the Inquisition. The persecutions to which he was subjected by this "sacred court," lasted with short intervals almost twenty years. The wearisome trials and his incarcerations from time to time only ceased with his retractation. On June 22d, 1633, Galilei, at the age of seventy years, on his knees, and clad only in a shirt of sackcloth, was forced (by torture?) to pronounce in the presence of his judges and a large assembly of prelates, a most humiliating formula of abjuration. It has been asserted that he added in a whisper, "E pur si muove," (still it does move), meaning the earth.

*Galvani*, Luigi (1737-98), an Italian physicist and celebrated anatomist; discovered accidentally the electric current produced by connecting two metals of different density, called after him "Galvanism." All electroplating is based on this discovery.

*Gascoigne*, W. (1612-44), an English astronomer and mechanic; improved the grinding of lenses. He was the original inventor of the wire micrometer, of its application to the telescope, and of the application of the telescope to the quadrant.

*Godfrey*, Thomas, born in Philadelphia; worked as a glazier in his native city, and studied mathematics with great energy; he even learned Latin in order to read mathematical works in that language. In 1730, he communicated an improvement he had made in the quadrant, and the invention was laid before the Royal Society in London. In the mean time, John Hadley had made a very similar invention, and each of them was awarded the prize of £200. Godfrey died in Philadelphia in 1749.

*Graefe*, Albrecht von (1828-70), the most celebrated German oculist; studied medicine at Berlin, Vienna and

Paris; established 1850, at Berlin, a clinic for eye-patients, and was in 1856 elected professor of ophthalmology. He is the founder of modern Ophthalmology, greatly assisted by the invention of Helmholtz's ophthalmoscope, which received in Graefe's hands its highest recognition.

*Graham*, George (1675-1751), an English watchmaker and optician; invented the compensated mercury pendulum, also the cylinder escapement, and the dead-beat escapement for clocks. He constructed the sextor with which Bradley, at Oxford, detected the aberration of light, and executed a great mural-arc for professor Halley, a celebrated English astronomer (1656-1742), at the Observatory of Greenwich, who calculated the course of twenty-four comets; one of them bears his name.

*Gregory*, James (1638-75), a Scotch mathematician, invented at the age of twenty-four, the reflecting telescope known by his name. When he went to London with the view to the construction of his telescope, he found the opticians he employed wanting in the skill necessary for grinding the metal of the object-speculum into a conic section to correct spherical aberration; therefore, he abandoned the manufacturing plan, and devoted himself to the study of astronomy. [See James Short.]

*Grimaldi*, F. M. [1613-63], an Italian jesuit and great mathematician; his valuable work on light was published two years after his death. He was the first who described the "phenomena of diffraction," or the bending of waves of light around the edges of opaque bodies. Newton could not explain this phenomenon by his emission theory, but Young and Fresnel demonstrated its correctness by the wave theory on the "principle of interference."

*Guerike*, Otto von [1602-86], the ingenious burgomaster of Magdeburg, is renowned as the inventor of the air-pump and as the originator of many experiments in

natural philosophy. He introduced his invention by constructing two hollow hemispheres of brass, which fitted air-tight upon each other, and which could not be pulled asunder, after he had exhausted the air out of them, but by the application of great force. They are called the Magdeburg Hemispheres, and are still used in experimental physics to show the immense atmospherical pressure upon a vacuum.

*Guinand*, François, (1745-1825), a Swiss watchmaker and optician, was the son of a carpenter, and first employed by the celebrated mechanic Jaquet-Droz, to make wooden cases for clocks, and later on, metal cases for watches. His employer had a fine English reflector which G. so perfectly imitated that it was difficult to decide which of the two was better. Droz being aware of the talent of his workman, instructed him in the science of optics, in the manufacture of spectacle glasses, and in the construction of achromatic lenses. He now studied chemistry, and commenced to perfect the fabrication of lenses for telescopes. Some of these coming under the observation of Fraunhofer, he engaged his services. The phenomenal improvements of achromatic instruments is due to the combined efforts of these two skillful men.

*Hadley*, John, [died 1744], an English astronomer, greatly improved the quadrant by turning it into a sextant, about the year 1731. [See Godfrey.]

*Harrison*, John, [1693-1776], a celebrated English watchmaker, learned from his father the trade of carpenter, made several clocks of wood with a newly constructed pendulum [1726]. He then commenced to make watches of metal with improvements of his own invention, until 1736, he produced a marine chronometer for which he received the medal. Captain Byron took one of his chronometers along on the "voyage round the world," 1764-66, and it proved to be a perfect time-piece; he, therefore, claimed the prize of £20,000, which the government had offered for the best chronometer.

*Helmholtz*, H. L. F., born 1821 at Potsdam, Prussia, is at present the most famed physicist in Germany. He studied medicine at Berlin, and was, 1848, appointed professor of anatomy. The next year he went to Königsberg as professor of physiology, where he stayed till 1855, when he was called to Bonn. In 1858 he accepted the professorship of physiology at the University of Heidelberg. His principal publications are "Conservation of Force," 1847; "Handbook of Physiological Optics," 1856; "Theory of the Impressions of Sound," 1862; "Popular Scientific Lectures," 1865-71; besides many other valuable scientific papers. He is the inventor of the Ophthalmoscope, an instrument which has totally revolutionized the science of Ophthalmology, and which is at present indispensable to any oculist. He is the survivor of the illustrious triumvirate "*Graefe*, *Helmholtz*, *Donders*," who raised Ophthalmology to an exact science. Their names will be remembered as long as a grateful posterity will cherish the achievements of great men.

*Herschel*, F. William [1738-1822], born in Hannover, educated a musician, emigrated 1757 to England, devoted most of his time to the study of astronomy; but being too poor to buy a telescope, he built, 1774, a reflector five feet long. With the assistance of his brother, who was a skillful mechanic, he constructed, 1785, a telescope of forty feet in length, which was the most powerful instrument at that time, and with which he made many discoveries, He discovered the planet Uranus, and some of his moons, also two moons of Saturn.

*Herschel*, Sir John, [1792-1871], followed in the footsteps of his celebrated father, whom he greatly exceeded in profound mathematical science, as well as in the long list of his astronomical researches and discoveries. In 1830 he published a treatise "On the Theory of Light," comprising his investigations in the optical department, which he had made in conjunction with Faraday. In 1838, Queen Victoria created him a baronet. He was an indefatigable explorer, and the most successful astronomer of this century.

*Heurteloup*, Nic., [1750-1812], celebrated surgeon in the French army; invented the artificial leech.

*Hipparchus*, considered the founder of the science of astronomy; lived about 150 years before Christ, and was born at Nicæa, Bithynia [Minor Asia]. Of his life nothing is known, and of his writings only one book has been left to us; but Ptolemy tells us of his great discoveries, and refers to him in many cases as an authority.

*Hooke*, Robert, [1635-1703], watchmaker at London; invented, 1658, the balance spring [hairspring], also the anchor-pallets for clocks, and a sliding-weight to the pendulum, to adjust the center of gravity with greater precision.

*Huyghens*, Christian, [1629-95], of The Hague, Holland; one of the greatest discoverers in mathematics, physics and astronomy. He discovered the law of double refraction in crystals with one axis, opposed the "emission theory" against Newton, and founded the "undulatory theory." He improved telescopes, ground and polished the lenses himself, and introduced the connection of the pendulum with clock-work. He also discovered the ring and the fourth satellite of Saturn. [See Galilei].

*Jaeger*, Edward, son of the celebrated Frederick Jaeger, is professor of ophthalmology at the University of Vienna, Austria. In 1854, he published his test-types, ranging from the finest to very large letters, in different languages. Among his many excellent publications, the most famous is his "Atlas of Ophthalmology", the original drawings of which were afterwards purchased by Dr. Norris of Philadelphia for about $2000.

*Johnston*, J. M., born 1844 in Western New York, an able optical writer; was educated for the Church, but entered, 1880, the Johnston Optical Company. He issued 1886 the "Eye-Echo," the first journal in America devoted exclusively to optics, and as a continuation of

the former, since 1891, the "Eye-Light." In 1892, he published a valuable work, "Eye Studies, a series of lessons on vision and visual tests".

*Kepler*, John, [1571-1630], a German mathematician and astronomer of great reputation; was one of the founders of modern astronomy. His three laws [Regulae Kepleri] of the elliptical orbits of the planets were afterwards accepted by Newton, and are still in use. He invented the astronomical telescope in which the objective and ocular lenses were both convex. He was the first who explained the true theory of vision.

*Kircher*, Athanasius, (1601-80), a very learned Jesuit; was born in Germany, but lived mostly in France and Italy. He invented the Magic Lantern, and constructed a powerful burning-mirror with which he experimented on the Island of Malta; it is known by the name Maltesian Mirror.

*Kirchhoff*, G. R., [1824-87], celebrated German physicist, born at Königsberg, Prussia; studied mathematics and physics, went 1847 to Berlin as professor of physics, 1850 to Breslau, 1854 to Heidelberg, and 1875 again to Berlin. His scientific researches were mostly directed to electricity, galvanism, and to the peculiar properties of bodies and gases. His investigations of the Fraunhofer's lines, which he made in conjunction with Bunsen, led them to the discovery of "spectrum analysis."

*Knapp*, H., celebrated oculist of Germany and America; was born 1832 in Nassau, Germany; studied for nine years medicine at Munich, Berlin, Leipzig, Vienna, Paris, London and other celebrated Universities. He was lecturer and later professor of ophthalmology in Heidelberg, but resigned in 1868, and settled in New York City. Here he published the Archives of Ophthalmology and Otology, and founded the N. Y. Ophthalmic and Aural Institute. He was for several years professor of ophthalmology at the Medical College of the University of N. Y., and is at present professor of ophthalmology at the College of Physiology and Surgery at

New York. He is regarded as an authority in medical circles, in America as well as in Europe. In 1873, he introduced some very valuable improvements in the Ophthalmoscope.

*Lieberkühn*, J. N. [1711-65], physician at Berlin; invented, 1738, the solar microscope.

*Lippershey*, John, the inventor of spyglasses, about the year 1600, was born in Wesel, Germany; his real name was Hans Lippersheim. He established himself as an optician at Middleburg, Holland. It is told that one day his son was playing with old spectacle lenses, and accidentally put a convex lens at one end of a hollow tube and a concave one at the other end; then called the attention of his father to the strange phenomenon, that distant objects seemed to be so near-by, that he fancied he almost could touch them.

*Littrow*, J. J., [1781-1840], studied at Prague, was engaged at different universities as professor of mathematics and astronomy, until in 1819, he became director of the Observatory at Vienna. Some of his theoretical publications induced the optician Ploessl to construct the dialytic telescope. His most popular publications are: "The Wonders of the Heavens," and "Maps of the Starred Heavens".

*Malpighi*, Marcello, [1628-94], an Italian anatomist; was the first to employ the simple microscope to investigate the anatomical structure of plants and living animals; thus he discovered the capillary circulation of the blood from the arteries to the veins. Various parts of the epidermis, spleen and kidneys still bear his name.

*Malus*, E. L., [1775-1812], a French physicist, was educated at the school of military engineers; was a great mathematician, but took a fancy to the study of the mathematical theory of optics. For the greater portion of his short life he was attached to the French army, and took part in the adventurous expedition of Bonaparte

[Napoleon I] to Egypt. In 1801, he returned to Paris, and although his health was broken down, his spirit was yet in the prime of life. In 1808, the French "Institute of Sciences" offered a prize for the best essay on double refraction in crystals. Malus competed for the prize, and in the course of his experiments discovered the phenomenon known as the *polarization of light*. He advanced the theory "that particles of light have poles, and that on entering a doubly-refracting crystal, some of the particles forming one of the rays may be so arranged as to be transmitted through it, while the particles which should have formed the other ray may be so arranged as to prevent the transmission in certain directions." This discovery introduced a new diversion of physical optics. In 1810, he published his "Treatise on Optics," and his "Theory of the double refraction of light in crystals".

*McAllister*, John, [1753-1829], born in Scotland, emigrated to America in 1774, and started, 1796, an optical business in Philadelphia. John McAllister jr. [1786-1877], a graduate from the University of Pennsylvania, associated with his father in 1811, and laid the foundation of an extensive business. The war of 1812 stopped the importation of spectacles, and compelled them to manufacture all gold and silver spectacles themselves. In 1836, Walter B. Dick and Jas. W. Queen became partners, till 1853; the firm, McAllister & Co., was then continued by him and his son, W. Y. [born 1812], until 1865, when the father retired. In 1882, W. Y. McAllister took his son, W. M. [born 1843], as partner; another son, F. W. [born 1853], started an optical business in Baltimore, 1879, and is the inventor of an improved nose piece.—This remarkable "family of opticians" will soon celebrate its centennial.

*Merz & Mähler*, the skillful successors of Fraunhofer, at Munich; turned out many astronomical telescopes, among them the famous refractor of the Pulkowa Observatory in Russia, also that of the Harvard University in the U. S.; both instruments contain object lenses of fifteen inches aperture.

*Mudge*, Thos., [1710-94], an English mechanic; was an apprentice of the celebrated Graham, and became the most skillful watchmaker in Europe. The English government paid him for the superiority of his chronometers the prize of twenty-five hundred pounds sterling. He invented the lever escapement.

*Newton*, Sir Isaac, [1642-1727], the most remarkable mathematician and natural philosopher of his age, was the founder of modern mathematical physics and physical astronomy. In 1665 he discovered the law of universal gravitation; he then studied the nature of light, and detected by means of prisms the composition of white light, which led him to the grinding of lenses, and to the construction of reflecting telescopes. In 1704 he published his "Optics, or a treatise on the reflections, refractions, inflections and colors of light;" and in 1713 his "Principia." He was the founder of the "emission theory."

*Nicholson*, W. [1753-1815], English physician and chemist; invented the areometer or hydrostatic balance, that bears his name. He published about twenty scientific works mostly on chemistry.

*Nicol*, W., [1768-1851], a lapidary at Edinburgh; invented the polarizing prism of Iceland spar, which totally reflects the ordinary ray, whilst the extraordinary passes through, and which bears his name. His skill as a working lapidary was very great; he executed a number of lenses of precious stones, especially of garnet, which lenses he preferred to the achromatic microscopes of his time.

*Porta*, Battista, (1540-1615), an Italian astronomer, founded an academy in Naples to which no one was admitted unless he had made some discovery in natural philosophy. He was accused of magic and compelled by the pope to dissolve his academy. He wrote many volumes on natural magic, geometry, optics, etc.; also invented the *camera obscura*, and demonstrated that visual

perception is not effected by rays emanating from the eye, but by rays reflected from objects. (See Alhazen).

*Prentice*, James, (1812-88), eminent American optician; was born in London, served an apprenticeship of seven years with Elliott & Son, opticians and mathematical instrument manufacturers in London. He emigrated to America in 1842, and almost immediately secured the government patronage of the U. S., which he continued to supply with instruments until the beginning of the war, 1860. The superior excellence of his instruments gained for him a far-reaching reputation among architects and engineers. He received nine medals and four diplomas of honor between the years 1842 and 1860. After the opening of the war, he devoted his entire attention to the store which he had just previously opened. In 1867, he invented and patented the "anatomical eyeglass," since universally known as the *Prentice eye glass*, which was the *beginning* of improvements in eyeglass-frames; numerous patents by others soon following it.

*Prentice*, Chas. F., son of James Prentice, was born in Brooklyn, 1854; attended the Royal Polytechnicum at Carlsruhe, Baden, from 1871-74. It was his father's desire that he should give particular attention to mechanics, physics and mathematics, in order to become a thorough optician, as the father justly anticipated that the great development of the optical trade would lay greater claim to the ability of the future optician. After his return to America, he temporarily accepted the position as mechanical draftsman at the shipyard of John Roach in N. Y.; but in 1878 he entered his father's business, where he became a partner in 1883, and since 1888 its proprietor. His former theoretical studies soon made him the foremost optical writer in America. In 1886, he published his valuable "Treatise on Ophthalmic Lenses;" in 1888, his mathematical and most scientific "Dioptric Formulæ for Combined Cylindrical Lenses," and in 1890, his "Metric System of Measuring Prisms." He simultaneously invented the "Prismometer," to determine the refractive properties of prisms by their deviation; a new,

simple and most ingenious method, which enables oculists and opticians to experiment with prisms in a more scientific manner than ever before.

*Ptolemy*, Claudius, an Egyptian astronomer, flourished at Alexandria in the middle of the second century after Christ. He wrote the "Syntaxis Mathematica," which is a representation of the science of astronomy of that time, based partly on his own researches, partly on those of Hipparchus. As it is the only authority we have for the views of astronomy entertained by the ancients, and as it formed the foundation of all astronomical science down to the time of Copernicus, the book is consequently of the greatest interest.

*Queen*, James W., [1812-90], an American optician; learned his trade at the establishment of John McAllister at Philadelphia, in which he afterwards became a partner. In 1853, he commenced business for himself and gradually built up the largest scientific optical house in America.

*Ramage*, optician at Aberdeen; constructed, 1820, a Newtonian telescope at the Royal Observatory of Greenwich. The speculum has a focal length of twenty-five feet, and a diameter of fifteen inches. It was at that time the largest instrument in Europe.

*Ramsden*, Jesse, (1735-1800), an English optician of rare skill; was a dry-goods clerk; learned engraving on copper; had to engrave many illustrations of optical instruments, which induced him to learn the trade with John Dollond. Already in 1763, his instruments had a great reputation. He made many improvements and inventions, of which his "dividing machine" is the most important. He constructed some "mural circles," one of five feet diameter for Palermo, Italy, and one of eight feet for the Observatory at Dublin. The error of one of his quadrants (at Padua) was only two seconds.

*Reaumur*, R. A. F., (1683-1757), celebrated French physicist; divided the scale of the thermometer from the

freezing to the boiling point of water, into eighty degrees. His thermometers were filled with colored alcohol, which is preferable in great cold, as mercury will freeze at a temperature of forty degrees below zero, while the severest cold has never yet frozen pure alcohol.

*Reichenbach*, Geo., [1772-1826], became with Fraunhofer the ornament of the "Mechanical and Optical Institute of Bavaria" at Munich. His astronomical instruments, meridian circles, transit instruments, equatorials, heliometers, etc., made an epoch in "observing astronomy."

*Riddell*, J. L., [1807-67], of New Orleans, was professor of botany and chemistry at the University of Louisiana, 1836-65. He was the original inventor of the binocular microscope, 1851, which was afterwards manufactured and introduced by J. W. Stephenson of London. He also constructed an achromatic binocular magnifier in the form of spectacles, leaving both hands of the operator free for manipulation, and which is still in possession of the well-known oculist, Dr. Cornelius Beard, formerly of New Orleans, now in Boston.

*Rittenhouse*, David, [1732-96], an American mathematician; made the first telescope ever constructed in America. He learned clock-making, and established himself, 1751, in Norriston, near Norristown, Pa., as a clock and mathematical-instrument-maker. His days were spent in following his trade, and his nights were given to study. His orrery exhibits almost every motion in the astronomical world; it was bought by the University of Pennsylvania for £400. In 1770, he removed his business to Philadelphia. His scientific instruments displayed unusual mechanical and mathematical genius.

*Rochon*, Alexis, (1741-1817), a French astronomer; was first abbot of a convent, but quitted the church, and studied optics and astronomy. In 1777, he constructed a micrometer of rock crystal to measure small angles. He made several scientific expeditions to French colonies in Africa and East Indies, and found in Madagascar the

finest rock crystal which he ground into lenses; but declared them, afterwards, to be unfit for spectacles on account of their double refraction.

*Roemer*, Olans, (1644-1710), Danish astronomer; discovered the *velocity of light* by the eclipses of the first moon of Jupiter. The other three moons were not so favorable for this observation, as their mutual attraction makes their motion more complicated, and puzzled the astronomers, till Newton published his theory of universal gravitation, which solved the mystery.

*Rosse*, Lord W. P., (1800-67), the distinguished constructor of the largest reflecting telescope. In 1845, he built his great reflector, which up to the present day has remained without a rival. It has a focal length of fifty-four feet, and the tube is about seven feet in diameter.

*Saxton*, Joseph, (1799-1873), a skillful American mechanic; was apprenticed to a watchmaker, went 1817 to Philadelphia, where he worked at his trade, but devoted much time to drawing and engraving. He constructed an astronomical clock with an escapement on a new plan. In 1828, he went to England, where he made many ingenious mechanical toys, and exhibited, 1833, a magneto-electric machine, with which he produced a brilliant electric spark, decomposed water, and exhibited the electric light between charcoal points. In 1837, he returned to Philadelphia, and accepted the position of constructor of the standard weighing apparatus of the U. S. mint. He invented the medal-ruler, the fountain pen, and other useful machines and appliances.

*Short*, James, (1710-68), born in Edinburgh; constructed about 1732, some telescopes for his own amusement. In his first telescopes the specula were of glass, as suggested by Gregory, but he afterwards used metallic specula only, and succeeded in giving to them true parabolic and elliptic surfaces. He then adopted telescope-making as his profession, and went to London. All his telescopes were of the "Gregorian" form, and

some of them have retained even to the present day their original high polish and sharp definition.

*Snell*, Willebrord, (1591-1626), a Dutch mathematician; discovered the "law of the sines," *i. e.* that the sines of the angles of incidence and refraction are constant for the same medium.—Kepler tried to find this law, but did not succeed.

*Snellen*, H., was the pupil and assistant of Donders, and since 1888, is his successor as attending oculist to the Netherland Eye Hospital; is also professor of Ophthalmology at the University of Utrecht, Holland. In 1868, he published his test-types which virtually solve the problem of registering vision.

*Spencer*, Chas. A., (1813-81), born in Lennox, N. Y., is considered the pioneer of scientific optics in this country. He received a classical education at different colleges, but his attention was soon drawn to more practical study and experiment by himself. In 1831, he settled in Canastota, N. Y., as a manufacturer of telescopes and microscopes. He issued a descriptive catalogue, "Optical, Philosophical, Mathematical, Chemical and other Instruments and Apparatus," which contained a list of prices of various sized reflecting telescopes, chiefly of the Newtonian and Gregorian construction; only a few small achromatic telescopes and microscopes were mentioned. The instruments of this character then in the country were imported ones, and probably the whole number of achromatic microscopes was less than a dozen. The fame of Powell, Ross, Chevalier and Amici instigated his ambition to surpass them. He commenced to construct objectives of a considerable larger angle of aperture than in the European instruments. He first used some of Guinand's improved flint glass, but afterwards made extended and costly experiments in the attempt to produce a glass of higher dispersive and refractive power, and was to a certain extent successful; although his chief success was his skill in giving his lenses such curves which nicely balanced the aberrations. Every microscope

was accompanied by some fine object-slides to show its power, and which gradually became so fine that the English microscopists could not resolve them with their instruments. The first microscope that attracted attention was made for Dr. Gilman in 1847. Spencer's name became at once famous. A great deal of his success was due to the encouragement he had from American scientists, such as Prof. J. W. Baily, of West-Point, Dr. John Torrey, Dr. Goring, Dr. Gilman and Dr. John Frey, of N. Y., Dr. C. A. Beck and Paul Goddard, of Philadelphia, Thomas Cole, of Salem, Mass., and others, who purposely hunted for finer and finer tests in order that Spencer should resolve them, which he did. It is delightful to read to-day the few letters which remain of the voluminous correspondence which was carried on between those early microscopists, when the new powers of the microscope were just being unfolded, and a whole world of original investigations, full of marvels and wonders, was opened before them. An almost boyish enthusiasm appears to have animated them, as is apparent in their familiar correspondence. Spencer was now fairly a rival of the best foreign artists, and was acknowledged by them as such. Instead of following up this special branch, he diverted his attention to the study of astronomy which was particularly fascinating to him, and his fondness for the telescope and telescopic pursuits never diminished, though he found in the development of the microscopical objective a more promising field for his genius. About the year 1854, he formed a partnership with A. K. Eaton, and in addition to the microscopical work, they completed various achromatic telescopes, among them the large Equatorial for Hamilton College, having an object glass of 13½ inches in diameter, and a focal length of 16 feet. This was then the largest telescope in this country, and in its performance it compared favorably with the best Munich instruments; its price was $10,000. In 1856, they entered into a contract with the Trustees of the Dudley Observatory at Albany, to construct a magnificent heliometer, for the sum of $14,500. It was agreed that Spencer should visit the principal workshops of Europe and the celebrated Observatories, in order that

the instrument might surpass anything hitherto made. While he was absent, his optical department was managed by R. B. Tolles, who had been for some years his pupil. At Spencer's return, after an absence of six months, a bitter controversy arose between some of the Trustees and Dr. B. A. Gould, the director of the Observatory, which suspended the work for years; in fact, the heliometer was never built. The partnership between Spencer and Eaton was dissolved after a few years; he, with the aid of his sons, still carried on the business, until the year 1873. In the fall of this year occurred the disastrous fire at Canastota, which destroyed nearly every shop in the village, and very nearly ruined Spencer. The fire commenced at night in a building opposite his shop, and lasted all night. So rapidly was the spread of the fire, that he nearly lost all his tools and machinery, the accumulation of many years of toil and skill, and a large amount of finished and unfinished work. Only the building was insured. Crippled, but not wholly disheartened, he and his sons, with what they had saved from destruction, commenced anew in a little barn for a workshop. In 1875, they moved to Geneva, N. Y., and for two years were connected with the Geneva Optical Works. From 1877, the business was conducted under the name of C. A. Spencer & Sons. During this period they received, at the Paris Exposition, the highest award, a beautiful large gold medal, for excellence of their microscopical objectives. In 1880, his son, Herbert Spencer, commenced business in Geneva under his own name, while his father remained in the old shop. Already the evidence of an over-tasked constitution and a too long-continued strain upon his mental powers had become painfully evident to his friends. He did but little work, and spent most of his time in reading, occasionally experimenting with some new combination, but always genial and pleasant to such of his old friends as from time to time visited him to talk over the past, and discuss the future of microscopy and science generally. He died, after a confinement to his room of three weeks, on Sept. 28th, 1881. — Spencer was a genius in the full sense of the word. Life was not to him a contest for the

possession of wealth; no man was ever more indifferent to this than he; if he had been anything else he would have accumulated a fortune. He never was satisfied with his work, no matter how perfect it was for that time; so it happened that very often it cost him much more to produce a given piece of work than the pay he received for it. Large as were the prices which his acknowledged skill enabled him to obtain, — prices which were only too willingly paid, so the work could be had at all, — yet his life, from boyhood, when with the enthusiasm of youth he saw a name and fame opening before him, up to the time when, enfeebled by age and disease, he entered the eternal rest, was one long struggle with poverty. Not for want of industry. No man was ever more industrious, but not in the way of the world. There is little money to be made in the tedious testing and "touching up" of that which any one else would have called perfect work, but which the artist is unwilling to let pass from his hands, except when stern necessity compels, so long as he can imagine something better; albeit to accomplish this better, may be the work of days, weeks, or even months of trial and ardent application.

*Tolles*, Robert B., (died 1888 in Boston); was the most skillful American optician. (To my greatest sorrow I could not attain any information about his life, although I have written a dozen letters to different parties; three to his surviving partner. Indeed, the historian of contemporaries travels a hard road).

*Torricelli*, E. (1608-47), an Italian philosopher and mathematician; invented the barometer, 1643. He was also a skilled optician; his single microscopes were of great perfection, also his lenses for telescopes.

*Tschirnhausen*, E. W., (1651-1708), a German mathematician, physicist and philosopher; erected a large glass foundry, principally for the grinding of burning glasses. One of his make is still in the Academy of Sciences at Paris, which is thirty-three inches in diameter, and weighs 160 pounds, but is full of imperfections.

*Tycho Brahe*, (1546-1601), celebrated Danish astronomer; enriched the science of astronomy very much, partly by his numerous observations, partly by inventing new instruments, for instance, the Mural Circles. He rejected the Copernican system, which in his time was not supported by the conclusive evidence we now have in its favor. In fact, Tycho's theory, which made the sun move round the earth, and all the other planets round the sun, explained all the phenomena then known equally well with that of Copernicus. In 1597, he emigrated to Germany, and settled at Prague, where Kepler became his pupil.

*Tyndall*, John, born 1820 in Ireland; studied in his leisure hours mathematics and natural sciences, mostly by self-tuition. In 1844 he intended to emigrate to America, but his subsequent appointment as a surveyor on an English railroad changed his mind. In 1848, he went to Germany for further study, where he attended the celebrated lectures on chemistry by Bunsen, at Marburg. His first scientific publication [in German] was "On the Magneto-Optic Properties of Crystals." On his return to England, 1852, he made the acquaintance of Faraday, whose successor he became a year afterwards, as professor of natural philosophy at the Royal Institution of London. In 1872, he made a very successful lecturing tour in the U. S., treating especially of light, heat and sound. His greatest merit as a scientist is his marvelous gift of imparting to the great mass a clear conception of the most knotty subjects, in a popular way.

*Volta*, Allessandro, [1745-1827], celebrated Italian physicist; invented 1777, the electrophorus, the electroscope and the endiometer. In 1782, he invented the air-condenser, [the opposite to Guerike's airpump]. But his greatest achievement was the practical application of the invention of Galvani, in constructing the so-called Voltaic Pile, the fore-runner of the Electric Lights.

*Watt*, James, [1736-1819], an English optician and inventor; filled from 1757 to 74, the position of an op-

tician at the University of Glasgow; then he associated himself with Boulton. In 1779, he invented a machine for copying letters; but his greatest accomplishment was the improvement of steam Engines, and the invention of steam condensers.

*Wheatstone*, Charles, [1802-75], an English physicist; was from early youth a musical instrument maker, which led him to investigate the laws of sound. In 1834, he was appointed professor of experimental philosophy in King's College of London, when he read an essay entitled "Contributions to the Physiology of Vision." This led to the invention of his stereoscope, which he first exhibited in 1838. He was also the discoverer of important practical applications in electrical science.

*Wilson*, James; made the first artificial globes manufactured in the U. S. He lived at Bradford, Vt., about 1812.

*Wollaston*, W. H., [1766-1828], an English chemist and physicist; practiced medicine till 1800, then went to London and devoted himself to chemistry and physics. He discovered in platinum the metals Palladium and Rhodium; improved the microscope by introducing "doublets;" invented 1807, the "camera lucida," and the "periscopic lenses." He also invented the "reflecting goniometer," a valuable instrument to measure accurately small angles of crystals. His improvements in the construction of galvanic batteries were afterwards greatly surpassed by the ingenious inventions of Faraday.

*Young*, Thomas, (1773-1829), the most profound investigator since Newton; studied medicine in London and Edinburgh, but devoted himself greatly to the study of natural philosophy, to mathematics and optics. As early as 1794 he published an "Essay on the act of seeing, and on the peculiarities of the crystalline lens," in which he explained his own case of *astigmatism* not observed before by others. He is the scientific founder of

the "undulatory theory of light," and discovered the principle of "interference of light." His main work was published 1807, in two volumes, "Course of lectures on natural philosophy and the mechanical arts." His contemporaries considered him a "crank," but subsequent discoveries in the same line by the celebrated Frenchmen, Fresnel and Arago, and especially the able defense of the eminent German scientist, Helmholtz, and lately of Tyndall, have restored his fame forever.

*Zentmayer*, Joseph, a skillful optician of Philadelphia, died 1888. He was a native of Germany, and came to America in 1848. He invented several instruments of a scientific nature, for which he was awarded a gold medal in 1874. His microscopes are of the finest workmanship produced in America.

## CHAPTER XXVIII.

### MISCELLANIES.

*I. Problems for Inventors.*—The following suggestions are offered to the trade, in order to draw the attention of young opticians to these important subjects, and to direct their investigation into a proper channel.

1. Is there a test for the different qualities of glass ?

2. Can we illustrate by diagram, how two cylinders of the same strength, and at right angles, produce a spherical lens ?

3. Is there any perfectly transparent substance, or can it be manufactured, which will absorb all caloric rays, transmitting to the eye only the luminous part of the light ? (Mica is not perfectly transparent.)

4. What is the cheapest substitute for steel, so objectionable on account of its getting rusty ?

5. Can screws be omitted, and clamps and clasps be substituted without looking clumsy ?

6. Can the nose-bridge of spectacles be made moveable, up and down, out and in, or be made telescopic, to regulate its width according to pupil distance, without injuring the appearance or strength ?

7. Can we construct a contrivance to take the exact shape of the nose and the temporal width of the head, as a guide to a perfect fit of eyeglass and spectacle frames? The custom of dentists, to use pliable paste in taking impressions of the gum is, of course, excluded; but how about a device similar to that of a hatter, with small movable blocks of equal length, to show outside the same elevation as inside ? If the rods are placed parallel, at right angle to the bar, I think, it can be done, and be applied to any face without the least inconvenience to the customer.

*II. Corundum and Emery.*—Corundum in its pure state is composed of the oxide of aluminium. It is an exceedingly tough, compact mineral, occurring in a great variety of colors — blue, red, yellow, to nearly white. The pure crystals are translucent, and used as gems. It is one of the hardest known minerals, being placed in the scale of hardness next to the diamond. This quality is the source of its greatest value in the arts. The species are divided into three qualities — sapphire, corundum, and emery.

Sapphire includes the purer kinds of fine colors, transparent or translucent. These stones are used as gems, and are known by names indicating their color. The following well-known jewels are forms of this mineral: ruby, sapphire, oriental emerald, oriental topaz, and oriental amethyst. These gems are found chiefly in the beds of rivers in Ceylon, though some rubies are brought from Syria. The value of these stones was well known to the ancients, who used them under various names now obsolete. The stone called sapphire by Pliny is now known to lapidarists as *lapis lazuli*.

The oriental emerald is perhaps the rarest gem known. A few specimens have been found among the gold sands of the Missouri River, near Benton. But few of these jewels are in existence, and these are in the great collections of Europe.

Corundum generally means the dull, untransparent occurrences of the mineral. They vary in color—blue, gray, or brown—but are never clear or capable of being cut; it usually occurs in large, rough crystals, or in massive cleavages.

Emery is granular corundum. It is black or grayish-black in color, and mixed with grains of magnetite. Emery has very much the appearance of fine-grained iron ore, and for a long time was considered to be such. The texture is variable, some specimens being composed of almost impalpable grains, while others are made up of large, rough fragments of crystals.

Until recently the only source of emery was the far East, the Island of Naxos, in the Grecian Archipelago, containing the chief mines. The emery was shipped

from the port of Smyrna, and was known to commerce as Smyrna emery.

Emery and corundum are chiefly used in the arts as abrading and polishing materials. The mineral is ground, and separated by passing through sieves into classes of various dimensions, which are then further prepared in different ways adapted to the purposes for which they are to be used. For the use of jewelers and opticians, the fine emery is poured into water containing gum, and the coarser particles allowed to settle; the fine, impalpable dust remaining suspended in the liquid is then collected and used in polishing spectacle lenses, and similar articles. The largest amount of emery is used by the manufacturers of plate glass, though great quantities come upon the market prepared in a great many different shapes to suit special purposes. One of the largest of these industries is the manufacture of emery wheels; these are prepared by mixing the powder with glue or cement, and subjecting the paste to great pressure. Mixed with paper pulp and rolled into sheets, it is sold in the form of patent razor strops and knife sharpeners. Spread out on paper and cloth, it forms an excellent substitute for sand paper. Recently it has been discovered that crystallized corundum, when ground, forms a better abrading material than emery, owing to the fact that it breaks into sharp edged fragments, while emery has rather a rounded form. This discovery was followed by the discovery of large deposits of corundum and emery in Massachusetts, North Carolina, and Georgia. All of these localities are being actively worked, and large quantities of American material are being put on the market.

In the near future it is probable that corundum will assume a far more prominent place among the useful minerals as the source of the metal aluminium. The cheap production of this metal has long been the object of experiment to metallurgists; and corundum, furnishing the purest source from which it can be obtained, will probably be the most valuable ore.

*III. How to separate Lenses.*—The two lenses of an achromatic object glass are cemented together with

Canada balsam, the volatile part of which passes away, after a time, and it frequently happens that air or moisture, taking the place of this, gives an iridescent appearance to the glass and interferes with correct delineation. To remedy this fault it becomes necessary to separate and clean the two lenses and readjust them, cementing with Canada balsam, as before. Hitherto it has been customary, in order to effect the separation, to apply heat, and however carefully this may be done, it sometimes happens that a lens is thereby cracked. All risk of fracture may be avoided by placing the achromatic combination in a small quantity of benzole or naphtha (from coal tar) within a covered vessel, either of which hydrocarbons will, in a day or two, dissolve away or soften the hardened cement without heat. The same liquid will remove the last traces of resinous matter.

*IV. The Sharpening of Tools.*—Instead of oil, which thickens and smears the stone, a mixture of glycerine and spirit is recommended. The proportions of the composition vary according to the class of tool to be sharpened. One with a relatively large surface is best sharpened with a clear fluid, three parts of glycerine being mixed with one part of spirit. A graver having a small cutting surface only requires a small pressure on the stone, and in such cases the glycerine should be mixed with only two or three drops of spirit.

*V. A Dead Black Paint for Optical Instruments.*—Take two grains of lamp black, put it into any smooth, shallow dish, such as a saucer or small plate, add a little gold size and thoroughly mix the two together. Just enough gold size should be used to hold the lamp black together. About three drops of such size, as may be had by dipping the point of a lead pencil about half an inch into the gold size, will be found right for the above quantity of lampblack; it should be added a drop at a time, however. After the lampblack and size are thoroughly mixed and worked, add twenty-four drops of turpentine, and again mix and work. It is then ready for use. Apply it thin with a camel's hair brush; and when it is thoroughly dry, the articles will have as fine a dead black as they did when they came from the optician's hands.

*VI. Blue Eyes.*—It is said that all the Presidents of the United States, except Gen. Harrison, had blue eyes. Among the great men of the world blue eyes appear to have been predominant. Socrates, Shakespeare, Locke, Bacon, Milton, Goethe, Franklin, Napoleon and Humboldt, all had blue eyes; also Bismarck, Gladstone, Huxley, Virchow, Buchner, and Renan.

*VII. Effect of Colors on the Mind.*—An Italian physician lately made some interesting experiments in the treatment of lunatics. One patient was so melancholic that he refused all food. The physician transferred him to a red-colored, well illuminated room, and after a stay of three hours the melancholy had changed to an unrestrained gaiety, and the patient made no further objection to eat and drink. Another lunatic who was wildly excited, was brought into a blue room where he soon calmed into a tractable being. All other means tried before had failed.

*VIII. Blindness Due to Decayed Teeth.*—Dr. Widmark, a Swedish surgeon, having as a patient a young girl in whom he was unable to detect the slightest pathological changes in the right eye, but who was yet completely blind on that side, observing considerable defects in the teeth, sent her to a dental surgeon, who found that all the upper and lower molars were completely decayed, and that in many of them the roots were inflamed. He extracted the remains of the molars on the right side, and in four days' time sight began to return, and on the eleventh day after the extraction of the teeth it had become quite normal.

*IX. To Increase the Strength* of a cx lens, it is necessary to remove it from the eye. With a concave lens it is the reverse; its removal from the eye makes it weaker. A cc lens is strongest the nearer we approach it to the eye. If, therefore, a nearsighted person complains that his glasses fatigue the eyes, and trouble his vision, but that he sees more distinct when they are a little removed from the eyes; then we have to decrease the strength of his glasses one or more numbers, even at the expense of sharp vision for the first few days, till

the eyes are free from the overstrain of the former glasses.

*X. Direct Vision* is that which pertains to the very center of the eye; that which belongs to the rest of the eye is called *indirect* or *peripheral vision*. Indirect vision, although it may be very indistinct and imperfect in comparison with *central vision*, is, however, not less important than the latter. Without peripheral vision we would be in the condition of a man looking through a long, narrow tube which would allow of his seeing nothing but the object to which the axis of vision was directed. It would be impossible for him to see objects to one side without an incessant turning of the head.

*XI. How Science Advances.*—He who wishes to keep abreast with the march of science to-day must go to the work shop and into the dark corners of private laboratories; for investigators rarely have time to write, so that text books are years behind the science itself.

## CHAPTER XXIX.

### GLOSSARY.

*Aberration* (Latin). The deviation of light from the straight line.

*Albino* (Italian, whitish). One who lacks pigment in the skin, hair and eyes, therefore displays peculiar whiteness of the skin and hair, and a redness of the iris and pupil of the eye.

*Alkali* (Arabic, the soda-plant). A name given to certain substances, such as soda, potash and the like, which have the power of combining with acids to form salts.

*Amaurosis* (Greek, obscuration). Impairment or loss of vision from some undetectable cause,–see Amblyopia.

*Ametropia* (Greek, *ametros*, out of measure, *ops*, the eye). Is that condition of the eye, when parallel rays are focused either behind or in front of the retina.

*Amblyopia* (Greek, *amblys*, dull, *ops*, eye). Impaired vision from defective sensibility of the retina.

*Anatomy* (Greek, *ana temuein*, cutting up, dissection). The study of the different parts and the structure of the body.

*Aperture*. The opening of an angle. In good microscopes and telescopes, their aperture is often exceeding an arc of one hundred and fifty degrees.

*Aqueous Humor* (Latin, *aqua*, water). A few drops of watery, colorless fluid, occupying the space between the cornea, iris and crystalline lens.

*Aphakia* (Greek, *a*, not, *phakos*, lens). Absence of the crystalline lens; for instance, after the operation for cataract.

*Artery* (Greek, *aer*, air and *tereo*, to keep). A vessel conveying the blood from the heart outward to the or-

gans; so called because the ancients thought these vessels contained air, as they are empty after death.

*Asymmetry* (Greek, *a*, not, *syn*, with, *metron*, measure, not in measure). This word is the opposite of *symmetry*, which means that the several parts of a body, or thing, are in due proportion to each other; while *asymmetry* means that they are out of proportion.

*Asthenopia* (Greek, *a*, not, *sthenos*, strength, *ops*, eye). The eye has no strength in its muscles; sometimes "weaksightedness."

*Atrophy* (Greek, *trephein*, to nourish). A wasting away from defect of nourishment.

*Atropine* (Greek, *atropos*, black,—the name of one of the Fates). A very poisonous vegetable alkaloid, extracted from the plant Atropa Belladonna, the deadly nightshade; the extract crystallizes in long, white needles.

*Axis* [Greek, *axon*, a straight line, real or imaginary, on which a body revolves, or may revolve]. In optics, a ray of light from any object, which falls perpendicularly on the eye, called the optic or visual axis.

*Bi-focal*. A lens having two different foci.

*Binocular* [Latin, *bini*, two and two, *oculus*, eye]. It signifies an instrument used by both eyes at once.

*Binocle* (French). Eyeglasses for both eyes.

*Brain*. The mass of nervous substance contained in the cavity of the skull.

*Caloric* (Latin, *calor*, heat). The principle of heat, the agent of heat and combustion.

*Canthus* (Greek, *canthos*, the rim of a wheel). Angle of the eye; the inner and outer corners, where the eyelids join.

*Capillaries* (Latin, *capillus*, hair). The smallest blood vessels between the arteries and the veins, so called from their minute or hair-like size.

*Cartilage* (Latin, *cartilago*). A firm, elastic substance, like India-rubber, forming a part of the joints, wind-pipe, nostrils and ears.

*Cataract* ( Greek, *catarasso*, to throw down, to break or disturb). Opacity of the lens or its capsule.

*Catoptric* (Greek, *catoptron*, mirror). That part of optics which explains the properties of reflected light, and particularly that which is reflected from mirrors or polished surfaces.

*Cavity* (Latin, *cavus*, hollow). A hollow, inclosed space.

*Cerebellum* (Latin, diminutive of *cerebrum*, brain). The little brain situated at the back and lower part of the head.

*Cerebrum*. The brain proper, occupying the entire upper and front part of the skull. It is nearly divided into two equal parts, called hemispheres, by a cleft extending backward from the front part of the head.

*Choroid* (Greek, *chorion*, skin, *eidos*, form). A brownish-black membrane forming the middle coat of the eyeball.

*Choroiditis*. Inflammation of the choroid.

*Cilia* (Latin). Eyelashes.

*Concave* (Latin, *concavus*, hollow). Curved or rounded, like the inside surface of a hollow globe.

*Congestion* (Latin, *con*, together, *gero*, to bring). An unnatural gathering of blood in any part of the body.

*Contraction* (Latin, *traho*, to draw). The active shortening of a muscle or muscular fibre.

*Convex* [Latin, *conveho*, to bring together]. Curved or rounded, like the outside of a globe.

*Cornea* [Latin, *cornu*, horn]. The transparent, horn-like substance which covers the front part of the eyeball, through which the light passes.

*Crystalline Lens* [Latin, *crystallum*, ice,]. A transparent, circular body, rounded on its front and back surfaces, situated in the eyeball, just behind the pupil and iris.

*Deviation* (Latin, *de*, from, *via*, way). A turning aside from the right way or line.

*Dialyte* (Greek, *dia* and *lyo*, to loosen, to separate). A telescope in which the flint and crown glass of the objective lens are not glued together, but mounted separately, leaving some space between them.

*Diaphragm* (Greek, *diaphragma*, partition). A plate with a circular opening, used, in instruments, to cut off marginal portions of a beam of light.

*Diffraction* (Latin, *diffringo*, to break in pieces). A change which light undergoes, when, by passing near the border of an opaque body, it forms parallel bands or colored fringes.

*Dioptric* (Greek, *dioptomai*, I see through). That branch of optics which treats of the refraction of light and the properties of lenses.

*Diplopia* (Greek, *diplos*, double, *ops*, eye). Double vision.

*Dispersion* (Latin, *dispargo*, to scatter). The separation of light into its different colored rays.

*Dissolving views*, are produced by two magic lanterns of equal strength, whose foci are centered on the same spot of the canvas on which the picture is shown. By a skillful manipulation of the adjusting screws, one picture may gradually disappear while another almost instantly takes its place.

*Distance* (Latin, *disto*, to stand apart). Rays coming from a point nearer than twenty feet are divergent, and are considered as coming from a "finite distance;" but rays coming from a greater distance than twenty feet are *practically* parallel, and are considered as coming from an "infinite distance."

*Duct* (Latin, *duco*, to lead). A narrow tube, usually designed to convey away a secretion from the gland in which it is produced.

*Elasticity* (Greek, *elastreo*, to impel, or *elao*, to drive). The property of bodies by which they recover their former figure or size, after the removal of outside pressure or force.

*Emmetropia* (Greek, *metron*, measure, *emmetros*, in measure, *ops*, eye). The condition of the eye, when par-

allel rays are brought to a focus upon the retina without any effort of the accommodation.

*Focus* (Latin, hearth, fire-place). A point in which the rays of light meet, after being reflected or refracted.

*Glaucoma* (Greek, *glaucos*, sea-green). A most serious disease of the eye, not well understood, but characterized by hardness of the globe, dilatation of the pupil, and often by a greenish opaque appearance of the pupil.

*Goggles* (this word is of Welsh origin, *gogelu*, to shun, to shelter; the French, *coquille* is only a poor substitute for the same word). Protection spectacles of colored glass in the shape of a *muschel* or a hollow watchglass.

*Granulation* (Latin, *granum*, grain). The process of forming small grain-like swellings on the tender mucous membrane of the eyelid, a disease; also the natural process by which the surfaces of ulcers and sores are covered with new tissue,–granulation tissue or granulations.

*Horopter* An obsolete denomination for Range of Vision.

*Humor* (Latin). Moisture; the humors are transparent contents of the eyeball.

*Hyperaemia* (Greek, *hyper*, over or above, *haima*, blood). An active superabundance of blood in an organ, or part of the body.

*Illusion* (Latin). A deception of the sense (sight) or brain.

*Indentation* (Latin, *in*, and *dens*, a tooth). A notch in the margin of anything.

*Inflammation* (Latin, *flammo*, to flame). A peculiar diseased condition of any part of an animal body, characterized by redness, swelling, heat, pain and febrile symptoms; there is first hyperaemia and then congestion.

*Ingredient* [Latin, *ingredi*, to go into]. That which enters into a compound as one of its constituents.

*Iris* [Latin, the rainbow]. The thin muscular ring or curtain which lies between the cornea and crystalline lens, and which gives the eye its brown, blue or other color.

*Iritis.* Inflammation of the iris.

*Irradiation.* The phenomenon by which a brilliant body (especially on a dark ground) appears larger than it is, by reason of the stimulation of the light force, extending over a larger area of the retina than that occupied by the image of the body.

*Kaleidoscope* (Greek, *kalos*, beautiful, *eidos*, form, *skopeo*, to see). An instrument which, by an arrangement of reflecting surfaces, exhibits an infinite variety of beautiful colors and symmetrical forms of its contents.

*Latent* (Latin, *lateo*, to lie hid). Concealed, secret, hidden; not visible or apparent.

*Lens* (Latin). A piece of transparent glass, or other substance, so shaped as either to bring together or disperse the rays of light.

*Ligament* (Latin, *ligo*, to bind). A fibrous band or cord, serving to attach two bones to one another.

*Manifest* [Latin]. Clear, disclosed, apparent, evident.

*Membrane* [Latin, *membrum*, a limb or member]. A thin layer of tissue serving to cover some part of the body.

*Meniscus* [Greek, *meniskos*, a little moon]. A lens convex on one side and concave on the other.

*Mica* [Latin, *mico*, to shine]. A transparent mineral capable of being cleaved into elastic plates of extreme thinness. It is a poor conductor of heat.

*Microscope* [Greek, *mikros*, small, *skopeo*, to look at]. An optical instrument which magnifies objects.

*Mirage* [Latin, *miror*, to admire]. An optical illusion arising from an unequal refraction in the atmosphere, and causing remote objects to be seen double, as if reflected in a mirror, or to appear as if suspended in the air, like the "Fata Morgana."

*Monocle* [Latin, *monoculus*, one-eyed]. A single eye-glass.

*Motor* [Latin, *moveo*, *motum*, to move]. Causing motion; the name of those nerves which conduct to the muscles the stimulus which causes them to contract.

*Muscæ volitantes* [Latin, *musca*, a fly, *volito*, to fly about]. The appearance of grayish motes apparently before the eyes.

*Mucous Membrane.* The thin layer of tissue which covers those internal cavities or passages which communicate with the external air.

*Mucus* [Latin]. The sticky fluid which is secreted by mucous membranes, and which serves to keep them in a moist condition.

*Muscles* [Latin, *mus*, mouse, *musculus*, a little mouse]. A band of fibres acting as an organ of motion in animal bodies. The *voluntary muscles* act in obedience to the will, and contract suddenly; the *involuntary muscles* do not obey the will, and contract or relax slowly.

*Mydriasis* [Greek]. The unnatural dilatation of the pupil.

*Myopia* [Greek, *myo*, to shut, *ops*, the eye]. Nearsightedness.

*Myosis* [Greek], the unnatural contraction of the pupil.

*Nerve* (Greek, *neuron*, a cord or string). A glistening, white cord, connecting the brain or spinal cord with some other organ of the body. The nerves are the telegraph-wires of the body.

*Neuralgia* (Greek, *neuron*, nerve, *algos*, pain). A peculiar pain of a nerve of common sensation, not preceded or occasioned by any other disease.

*Objective lens.* The lens of an optical instrument which is directed to the object to be seen.

*Observatory.* A place or building for making observations on the heavenly bodies.

*Ocular lens.* The lens of an optical instrument through which the eye looks.

*Oculus dexter* (Latin, abbreviated O. D.). Right eye.

*Oculus sinister* (Latin, abbreviated O. S.). Left eye.

*Ophthalmia* (Greek, *ophthalmos*, the eye). Inflammation of the eye.

*Ophthalmology* (Greek, *logos*, a discourse). The science of medicine and surgery concerning the eye.

*Ophthalmoscope* (Greek, *skopeo*, to examine). The instrument for exploring the interior of the eye.

*Optic* (Greek, *opto*, to see). Pertaining to the sense of sight.

*Opticus* (Latin) Optician.

*Optometer* (Greek, *ops*, eye, *metron*, measure). Eye-measure; an instrument for measuring the limits of direct vision.

*Organ* (Greek, *organon*, an instrument). Any part of the body which is adapted to perform a particular service, such as the eye, etc.

*Oxide*. A compound of oxygen and a base.

*Oxygen* (Greek, *oxys*, sharp, *gennaein*, to bring forth). A gas forming one fifth part of our atmosphere, and essential to respiration.

*Panorama* [Greek, *pan*, all, *orama*, view]. A picture presenting from a central point a view of objects in every direction. It is lighted from above, and viewed from a platform in the center.

*Pantoscopic*, is the Greek name for double-focus, or so-called Franklin glasses.

*Papilla* [Latin]. Minute projecting filaments, being the termination of nerves, as on the tongue, also on the retina.

*Parabola*. A conic section arising from cutting a cone by a plane, parallel to one of its sides.

*Paralysis* [Greek, *paralyo*, to loosen, dissolve or weaken]. An abolition of the functions of motion.

*Perimeter* [Greek, *peri*, about, *metron*, measure]. An instrument to measure the field of vision.

*Periphery* [Greek, *peri*, around, *phero*, to bear]. The circumference of a circle.

*Periscopic* [Greek, *peri*, around, *skopeo*, to look]. To look about, a term applied to concavo-convex lenses.

*Phantasmagoria* [Greek]. A magic lantern, or its representations.

*Phenomenon* [Greek]. Anything visible, being presented to the eye by observation or experiment; an appearance whose cause is not immediately obvious.

*Photophobia* [Greek, *phos*, light, *phobeo*, to dread]. Intolerance of light.

*Pigment* [Latin, *pingo*, to paint]. Coloring-matter.

*Pince-nez* [French, *pincer*, to press, *nez*, nose]. Pincers, eyeglasses.

*Polarization.* A change produced upon light by the action of certain media, by which it exhibits the appearance of having polarity or poles, possessing different properties.

*Polyopsia* (Greek, *polys*, much). Seeing more objects than are present.

*Presbyopia* (Greek, *presbys*, old). Old sight.

*Punctum proximum* [Latin]. The nearest point of distinct vision.

*Punctum remotum.* The distant point of distinct vision.

*Pupil* [Latin, *pupilla*]. The central, round opening in the iris, through which light passes into the eye.

*Range of Vision.* The horizontal distance at which the eye is still able to discern objects.

*Reflector* [mirror]. A telescope in which the rays of an object are received by a mirror, and from it reflected to the magnifying ocular lens.

*Reflex action.* An involuntary action of the nervous system, by which an external impression conducted by a sensory nerve is reflected or changed into a motor impulse.

*Refractor.* A telescope in which the rays of an object are received and magnified by a set, or row of refracting lenses.

*Retina* (Latin, *rete*, a net). The membranous expansion of the optic nerve in the interior of the eyeball, which receives the impressions resulting in the sense of vision.

*Retinitis.* Inflammation of the retina.

*Sclerotica* [Greek, *skleros*, hard]. The tough, fibrous outer coat of the eyeball; the visible portion is the "white of the eye."

*Sensation* (Latin, *sensus*, sense). The conscious perception of an external impression by the nervous system; a function of the brain.

*Spasm* (Greek, *spasmos*, convulsion). A sudden violent and involuntary contraction of one or more muscles, or muscular fibres.

*Spectroscope*. An instrument to decompose light by means of prisms, which is used in the researches of Spectrum Analysis.

*Speculum* (Latin). A mirror, either plane, convex or concave.

*Staphyloma* (Greek, *staphyle*, a grape). A projection of some part of the eyeball, either of the cornea and iris (Staph. anterior), or of the sclerotica and choroid (Staph. posterior).

*Stenopæic Slit*. A blackened metal plate with a narrow slit in the middle, to detect the faulty meridian of an astigmatic eye.

*Stereoscope* (Greek, *stereos*, solid, *skopeo*, to see). An optical instrument for giving to pictures the appearance of solid forms as in nature.

*Strabismus* (Greek, *strabos*, twisted). The squinting of an eye.

*Striated* (Latin, *strio*, to furnish with channels). Marked with fine parallel lines.

*Symptom* (Greek, *syn*, with, *pipto*, to fall). A sign or token of disease.

*Tapetum* (Latin, *tapis*, tapestry). A shining spot to the outer side of the optic nerve in the eyes of certain animals, due to the absence of pigment.

*Temple* (Latin, *tempus*, time, *tempora*, the temples). The part of the head between the ears and the forehead; so-called because the hair begins to turn white with age in that portion of the scalp.

*Tissue*. Any substance or texture in the body formed of various elements; such as cells, fibres, bloodvessels, etc., interwoven with each other.

*Transparent* (Latin, *trans*, through, *pareo*, to appear). Capable of allowing light to pass through. Transparent bodies can be seen throngh.

*Vein* (Latin, *vena*). A vessel serving to convey the blood from the various organs toward the heart.

*Vibration* (Latin, *vibro*, to move to and fro). Quick motion to and fro.

*Vision* (Latin). The faculty or act of seeing external objects; the symbol is V.

*Vitality* (Latin, *vita*, life). The state or quality of being full of life.

*Vitreous* (Latin, *vitrum*, glass). Having the nature or appearance of glass.

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